THE BULLETIN

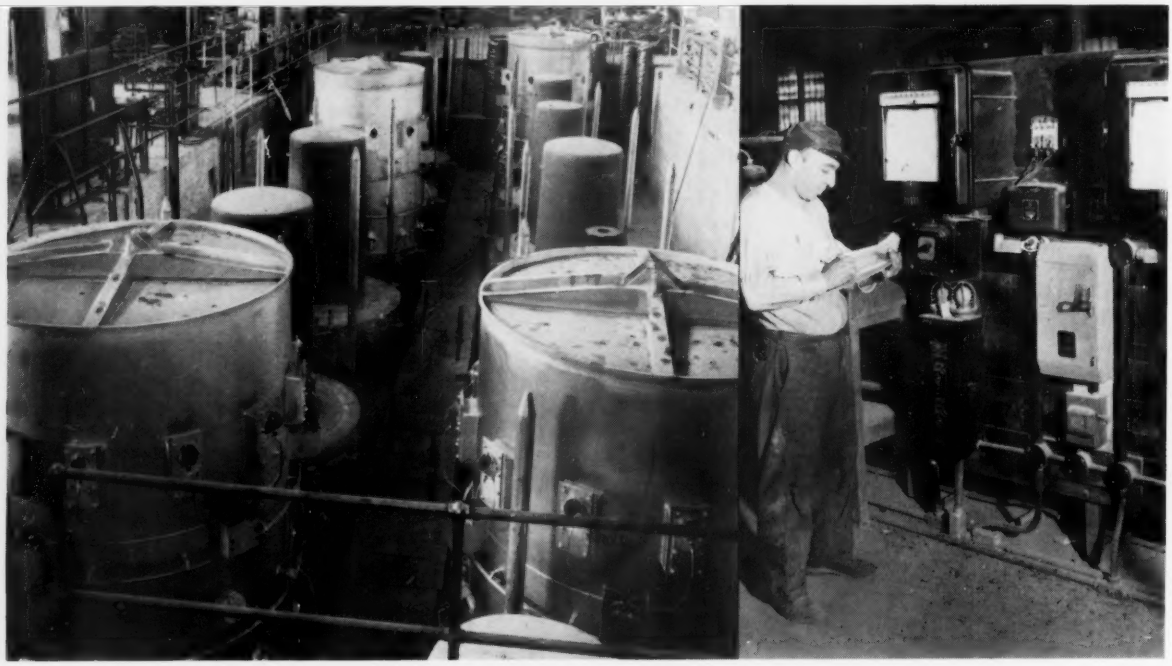
OF THE

AMERICAN CERAMIC SOCIETY

Volume 20 JULY, 1941 Number 7

ARTHUR L. DAY

For story, see page 252



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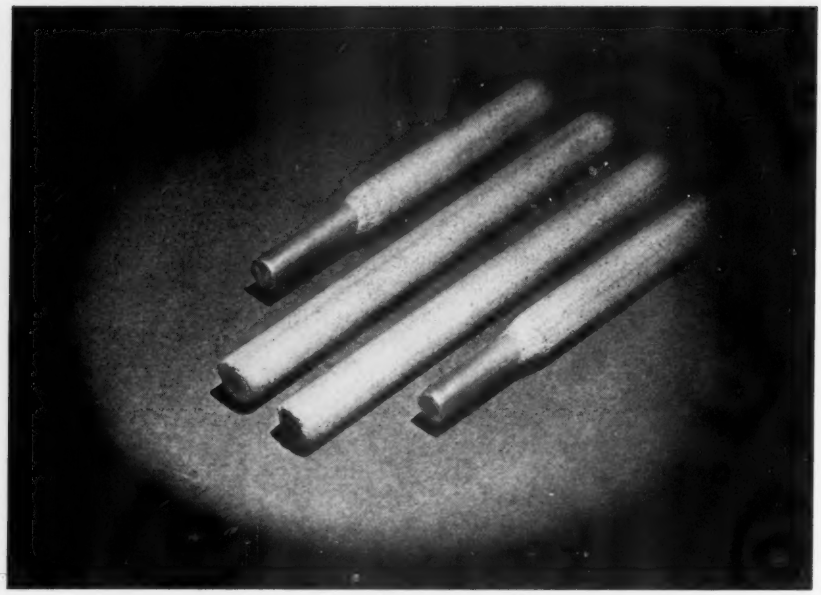

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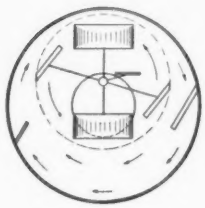

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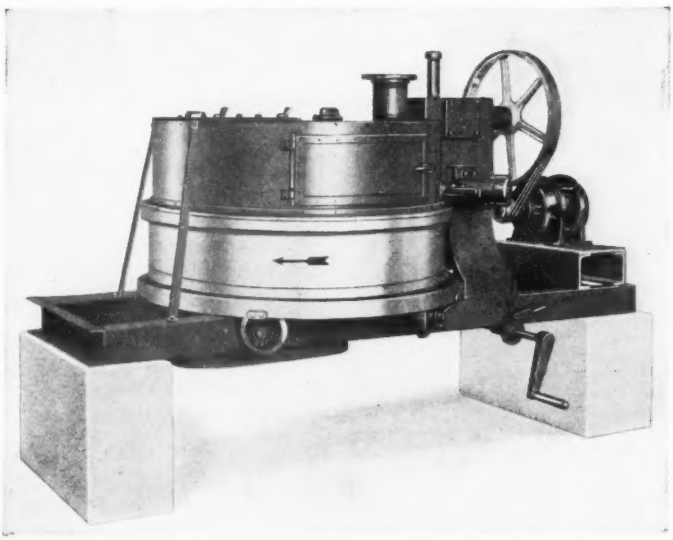

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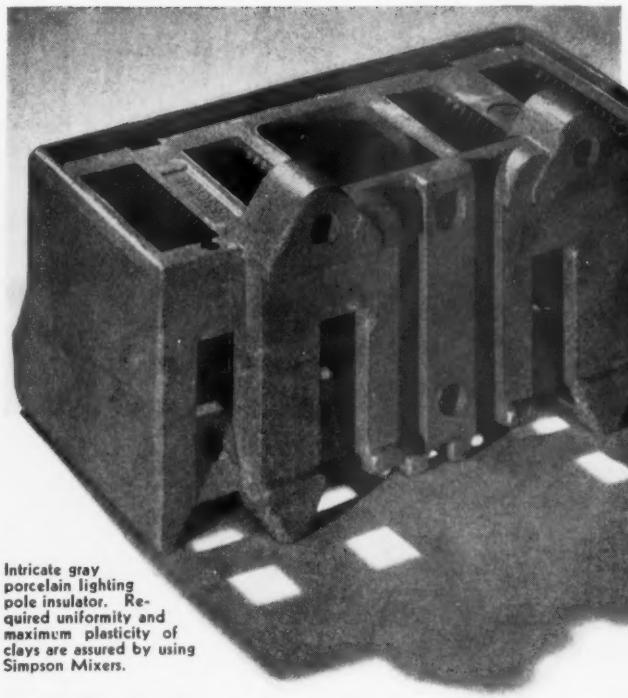

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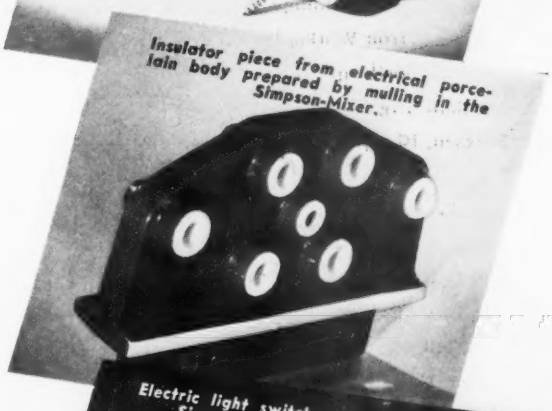

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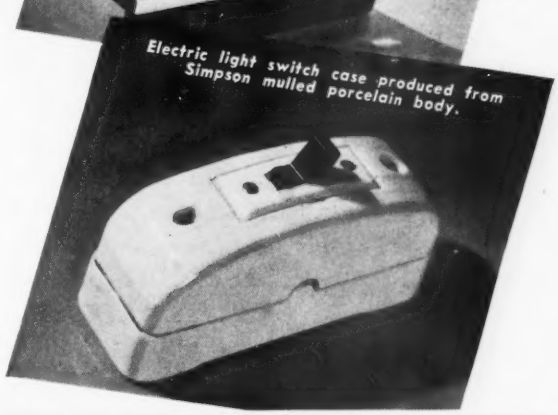

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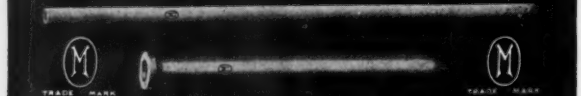

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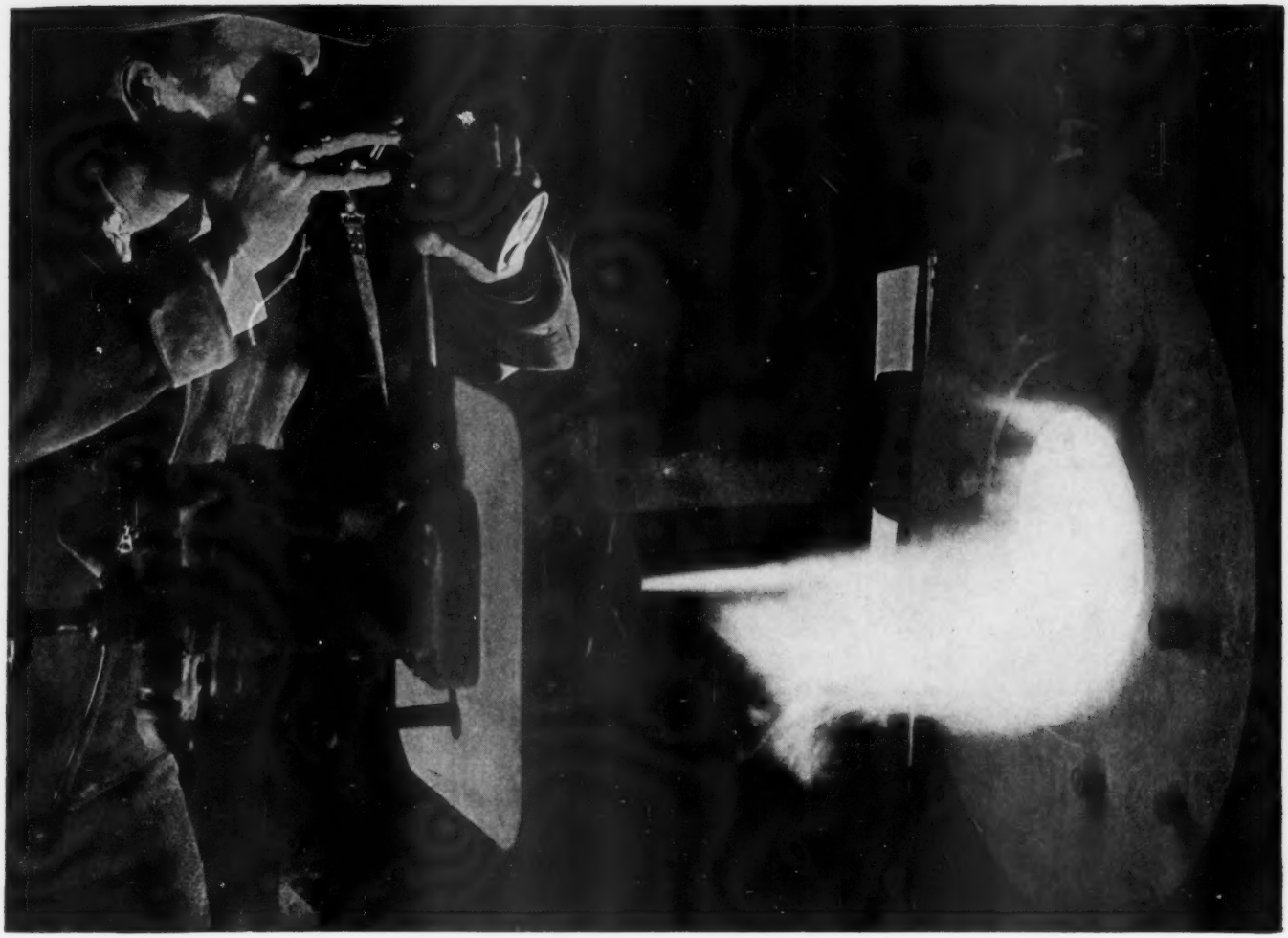

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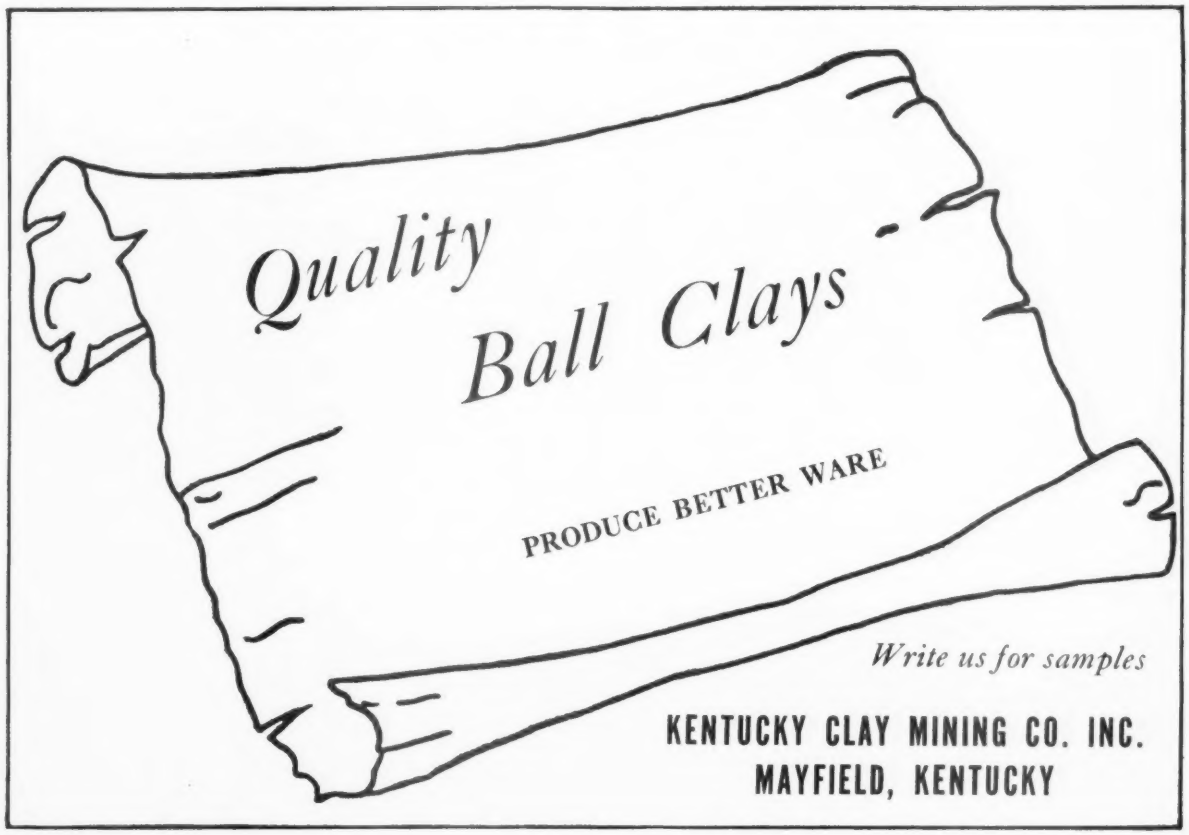

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A Monthly Publication Devoted to Proceedings of The Society and Promotion of Cooperative Research of Technical, Scientific, and Art Questions

Volume 20 **JULY, 1941** **Number 7**

PAPERS

TESTING REFRACTORIES AGAINST MOLTEN CALCIUM METAPHOSPHATE*

By Gordon R. Pole and A. W. Beinlich

Abstract

The production of crude calcium metaphosphate, containing about 65% of P_2O_5 and 26% of CaO involves the selection of refractories resistant to the corrosive action of the molten product. A laboratory method was developed for testing the commercial types of refractories under conditions similar to those existing in the operation of a large scale metaphosphate furnace. The corrosion test method that was adopted is described, and the results of tests on twenty-six refractories are given. An oil-fired, pot-type furnace with an inside diameter of 24 in. and 12 in. deep was used. Each test consisted in suspending four standard refractory shapes ($13^1/_2$ by $4^1/_2$ by $2^1/_2$ in.) from the furnace crown so that they dipped into a bath of molten metaphosphate to a depth of 2 to 3 in. The bath was maintained at 1300°C. for 66 hours. A linear flow of approximately 3 to 4 ft. per minute past the brick was imparted to the surface of the molten metaphosphate by the blast from the oil burners. Fresh metaphosphate was added at hourly intervals to maintain a constant bath level and as a means to compensate partly for the change in composition caused by the solution of the test brick. The degree of corrosion was measured by determining the volume and weight changes of each refractory.

The results obtained approximate those found in a large-scale plant furnace. Thin sections from a number of test brick were studied petrographically. The three most resistant refractories found by the method of testing were, respectively, zircon, high-silica vacuum-cast refractories, and dense stiff-mud brick.

I. Introduction

Few references occur in the literature concerning the corrosive action of molten calcium metaphosphate[1] or of phosphorus pentoxide vapor on refractories at high temperatures. Budnikoff,[2] who studied the effect of phosphate fusions on refractories by heating rock phosphate and mixtures of rock phosphate and coke to 1500°C. in holes cut in refractory pieces, concluded that refractories with a high alumina content (up to 43%) showed the highest corrosion resistance.

Vickers and Bell[3] described a method to test firebrick materials against the action of molten slags by injecting slag through a blowpipe against a hot refractory surface.

Endell, Fehling, and Kley[4] concluded that solubility, viscosity, and temperature were important factors affecting slag attack on refractories, and they emphasized the importance of keeping the surface temperature of the refractory, which is in contact with the slag, as low as possible. A modification of a furnace used in phosphate-slag tests and the test method used previously[5] were suitable for evaluating the relative resistance of refractories against metaphosphate.

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 2, 1941 (Refractories Division). Received April 3, 1941.

[1] (*a*) H. A. Curtis, R. L. Copson, and A. J. Abrams, "Metaphosphate Investigation Aims at Cheaper Fertilizers," *Chem. & Met. Eng.*, **44** [3] 140–42 (1937).

(*b*) H. A. Curtis, R. L. Copson, A. J. Abrams, and J. N. Junkins, "Full-Scale Production of Metaphosphate Achieved at Wilson Dam," *ibid.*, **45** [6] 318–22 (1938).

[2] P. P. Budnikoff, "Refractory Materials for Thermal Sublimation of Phosphorus from Phosphate Rock," *Khimstroi*, **6** [6] 341–43 (1934); *Ceram. Abs.*, **14** [2] 41 (1935).

[3] A. E. J. Vickers and R. A. Bell, "Apparatus for Investigating the Corrosive Action of Slags on Refractory Materials," *Jour. Soc. Glass Tech.*, **19**, 151–55 (1935); *Ceram. Abs.*, **16** [7] 206 (1937).

[4] K. Endell, R. Fehling, and R. Kley, "Influence of Fluidity, Hydrodynamic Characteristics, and Solvent Action of Slag on Destruction of Refractories at High Temperature," *Jour. Amer. Ceram. Soc.*, **22** [4] 105–16 (1939).

[5] G. R. Pole and D. G. Moore, "Testing Refractories Against Corrosive Action of Electric Furnace Phosphate Slags," *ibid.*, **19** [10] 259–70 (1936).

II. Experimental Methods

(1) Materials and Equipment

A standard shape, $13^1/_2$ by $4^1/_2$ by $2^1/_2$ in., was used as a test specimen for most of the tests. In a few cases (Table I), 9-in. standard straights were used by dovetailing one end to another to give the necessary $13^1/_2$-in. length. Table I gives the laboratory results of the physical and chemical properties of the various refractories used in the test.

The metaphosphate used in the corrosion tests was made in a laboratory pilot-plant furnace, and its composition was similar to that produced in the plant furnace.

The average composition of the metaphosphate was P_2O_5 66.7, CaO 25.3, SiO_2 4.1, Fe_2O_3 1.8, Al_2O_3 1.7, and F 0.43%. It was crushed to pass a 1-in. mesh screen before it was used in the test furnace.

The major part of the metaphosphate was glassy and varied in color from a light amber to brown with occasional light blue tints. The index of refraction of the glass, which varied with its composition, was 1.536 on a sample used in these tests. The metaphosphate devitrifies when it is cooled slowly, resulting in a crystalline material (sections of this material are shown in Figs. 9 to 14).

Figure 1 shows the construction details of the furnace and the arrangement of the test brick. A furnace of similar design was used in the slag-corrosion tests.[5] The side walls were built with superduty firebrick; the bottom was lined with a Corhart electrocast type of refractories; and a special Carbofrax shape which supported the four test brick was used for the top. The outside portion of the top was insulated with $2^1/_2$ in. of refractory insulating brick during the test. A sand-clay (80 to 20) mixture was used as a sealing agent between the top and side walls. A Carbofrax thermocouple tube extended to within 1 in. of the surface of the molten bath. The temperature was measured with a platinum–platinum 10% rhodium thermocouple connected to a recording potentiometer.

A furnace temperature of 1300°C. was maintained with two Hauck Venturi (No. 530) high-pressure oil burners, which were directed so that the flame impinged on the surface of the molten pool. The test brick were spaced so that they were exposed to a minimum of direct flame impingement.

(2) Method of Testing

Each refractory was examined for noticeable defects before it was tested, and its dimensions were measured to the closest $^1/_{16}$ in. The brick were dried at 110°C., weighed to the nearest gram, and given a thin waterproof coating by dipping in a shallow pan of molten paraffin, particularly the outside surface of the brick. The volume of the test brick was determined by the displacement method, using an overflow volumeter with water as the liquid medium. Where the volume appeared to be in error caused by water leakage through the paraffin coating, a check was made by weighing the test brick before and after the volume determinations. The volume of a test specimen of approximately 2500

TABLE I

PHYSICAL AND CHEMICAL PROPERTIES OF DIFFERENT BRANDS OF COMMERCIAL REFRACTORIES USED IN METAPHOSPHATE CORROSION TEST

Lab. No.	Refractory	Chemical composition (%)							Physical properties					
		SiO_2	TiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	ZrO_2	Appar. sp. gr.	Bulk sp. gr.	Absorption (%)	Porosity (%)	P.C.E.	Class No.*
A-1**	Firebrick†	51.5	2.1	1.8	41.7	0.7	0.8		2.61	2.31	5.0	11.6	32–33	2
C-1	Electrocast	17.5	3.0	1.0	77.6	1.2	0.3		3.33	3.26	0.8	2.1	36+	3
CN-1	"	11.7	1.3	1.8	59.6	1.0	0.4	22.9	3.77	3.63	0.7	2.4	36+	4
CR-1	Firebrick‡	26.4	3.5	2.6	65.1	1.8	0.5		3.07	2.34	10.2	24.0	34	4
CT-1	Zircon firebrick‡	33.8	0.2	0.6	3.1	0.0	0.0	62.5	4.46	3.48	6.4	22.1	>38	1
CZ-1	" "	24.2	1.0	1.4	2.9	0.7	0.0	49.5(1)	4.08	3.24	6.6	21.4	>38	5
E-1	Firebrick†	57.3	1.7	2.1	35.5	1.3	1.6		2.67	2.42	3.9	9.4	32–33	3
F-1	Vacuum-cast glass	67.6	1.8	0.7	28.1	0.7	0.4		2.58	2.08	9.3	19.4	30	2
G-1	Firebrick‡	53.4	3.3	0.2	42.8	0.1	0.1		2.71	2.33	6.2	14.3	33–34	3
HG-1**	Firebrick†	54.8	2.3	2.7	39.6	0.4	0.6		2.68	2.22	7.6	16.9	32	3
K-1**	Firebrick‡	53.1	2.1	2.1	41.9	0.8	0.3		2.67	2.37	4.7	11.0	33–34	2
KA-1**	Firebrick†	63.6	1.6	3.9	28.0	0.5	1.1		2.39	2.17	4.1	9.0	26	3
L-1	Zircon firebrick‡	35.3	0.3	0.9	4.2	1.1	0.0	58.1	4.36	3.56	5.2	18.4	>38	1
MH-1	Electrocast	1.9	0.6	0.8	32.1	15.1	49.3	(2)	3.34	2.63	8.1	21.3	34+	5
MK-1	"	2.7	1.6		70.4	0.0	5.3	(3)	3.87	3.54	2.4	8.3	36+	5
ML-1	"	1.2	2.0	0.8	93.0		0.4		3.77	3.59	1.3	4.7	36+	5
NA-1	Firebrick†	55.1	1.6	1.6	39.3	0.9	1.1		2.67	2.28	6.4	14.7	32–33	4
P-1	Wet-cast glass	60.9	1.9	0.5	36.8	0.6	0.5		2.62	2.18	7.2	15.9	31	3
T-1**	Firebrick†	61.3	1.5	2.0	32.5	0.7	0.1		2.61	2.24	6.4	14.2	30	2
TZ-1	Zircon firebrick‡	31.9	0.2	0.4	5.2	0.0	0.0	61.0	4.32	3.58	4.8	17.2	>38	1
W-1**	Firebrick†	60.4	1.8	2.3	30.5	0.5	1.2		2.47	2.22	4.4	9.8	27	1
WC-1	Vacuum-cast glass	65.6	2.1	1.7	29.5	0.1	0.2		2.63	2.14	8.9	19.0	30	2
WS-1	Firebrick†	54.4	2.2	2.1	40.2	0.6	0.4		2.63	2.23	6.8	15.1	32	3
WT-1	"	56.7	2.0	2.0	39.1	0.5	0.4		2.61	2.26	5.9	13.3	32	4
X-1	Firebrick†	24.5	3.5	3.8	66.9	1.3	0.5		3.11	2.59	6.5	16.4	36	4
Z-1	Zircon firebrick‡	32.4	Tr.	0.8	3.6	0.0	0.0	62.9	4.53	3.30	8.3	27.3	>38	1

* Class denotes relative resistance to metaphosphate.
† Stiff-mud.
‡ Dry press.
** 9-in. test brick.

(1) SiC 22%.
(2) Alkalis 0.5%.
(3) Cr_2O_3 7.9%, FeO 4.4%.

cc. could thus be determined within an error of less than 1%.

Stainless steel clamps, type No. 316, were fastened to one end of each brick with setscrews; the function of the clamp was to hold the brick at a constant depth of immersion when it was suspended from the furnace top (Fig. 1). A distance of 12 in. of suspension was maintained by placing the test brick in a rack similar to that described in the slag-corrosion tests.[5]

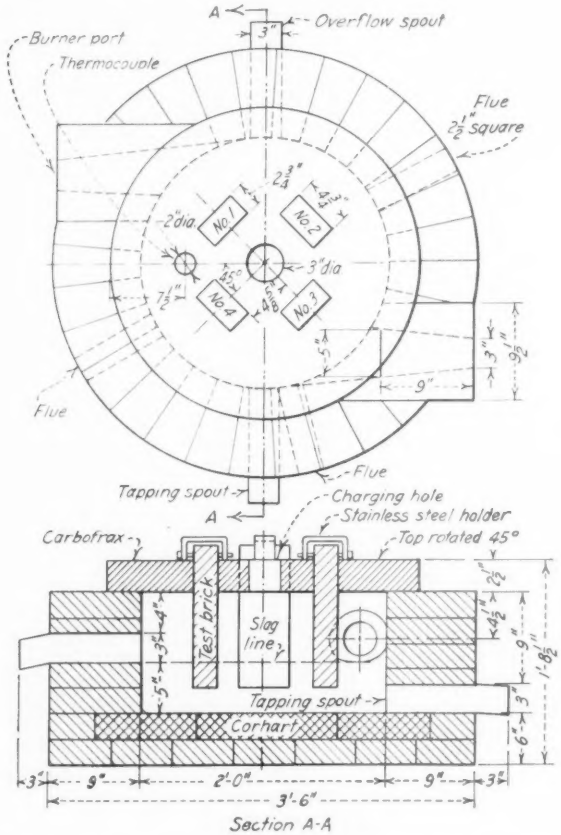

FIG. 1.—Construction details of test furnace and arrangement of test brick.

After the four test brick had been set in place, the heating was started with about one half of the charge of cold metaphosphate spread over the bottom of the furnace. The time of heating to 1300°C. varied from 5 to 6 hours, depending on the refractories tested; special care was exercised in heating the test brick that spalled easily, such as the silica, magnesite, and the fused-cast refractories. The two heating schedules are given in Fig. 2. Sufficient metaphosphate was added during the heating-up period to bring the molten metaphosphate level in the furnace to the bottom of the overflow spout (Fig. 1) by the time 1300°C. was reached, and additional metaphosphate was charged after the furnace had attained a temperature of 1000°C.

When the furnace had reached 1300° ± 10°C., this temperature was maintained as nearly as possible during the test period of 66 hours. The recording potentiometer was checked from time to time by a portable potentiometer. To maintain a constant level of molten metaphosphate and to compensate for the solution of the refractories, 5 pounds of cold metaphosphate were charged at hourly intervals. Short temperature drops of 30° to 70°C. were observed after each charge of metaphosphate, but in most cases the temperature of 1300°C. was regained within 5 to 8 minutes. During each test, the blast from the tangential burners caused the molten metaphosphate to move in a circular motion at a linear rate of approximately 3 to 4 feet per minute. The surface temperature of the ends of the test specimens projecting above the furnace top was estimated to vary from 375° to 500°C., depending on the composition of the refractory.

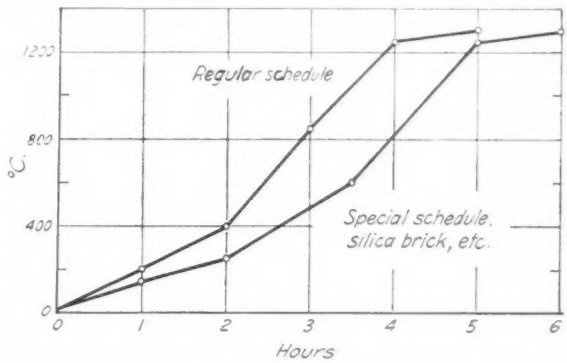

FIG. 2.—Heating schedules used in the test.

The molten metaphosphate was drained from the furnace at the end of each test by pushing in a firebrick plug which sealed the tapping spout. The furnace temperature was maintained as close to 1300°C. as possible during the tapping to let the glassy metaphosphate drain free from the ends of the test specimens. The burners then were cut off and the furnace cooled for 18 to 24 hours.

After the brick were removed from the furnace, the depth of immersion, the weight, and the volume of each were determined, and the weight and volume losses were calculated.[5]

Small slices were cut with a silicon carbide cut-off saw from a number of the corroded ends of the test brick. All of the sections were cut at right angles to the corroded surface of the brick and were rubbed down by hand to the proper thickness for petrographic study.

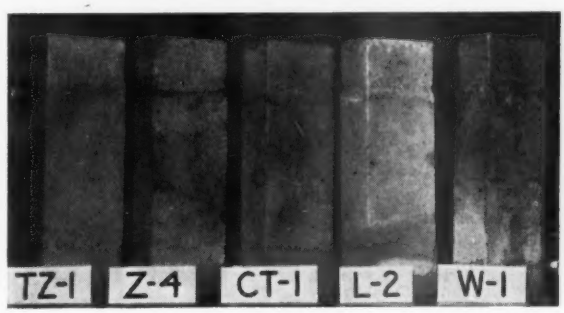

FIG. 3.—Class No. 1 refractory specimens after metaphosphate corrosion test.

III. Results

The results of the 66-hour corrosion test made on twenty-six brands of brick, together with the data used in calculating the weight and volume losses, are listed in Table II. Duplicate tests made on a number of brands are given, and the refractories are listed in order of decreasing corrosion resistance. The refractories were divided arbitrarily into five separate classes based either on the average weight or on the average volume loss. The five classes with the limits of the maximum volume or weight losses are as follows:

Classification of Corrosion Test Brick

Class No.	Limits of volume or weight loss (%)
1	0–4
2	4–8
3	8–12
4	12–16
5	>16

The refractories listed in Table III are classified in the foregoing order. This table gives a summary of the relative resistance of the various refractories to the 66-hour test. The brick are listed in the order of their maximum average weight or volume loss. A description is also given of the refractory after the test relating to the depth of flux line, the type of wash, and the appearance of the bottom end.

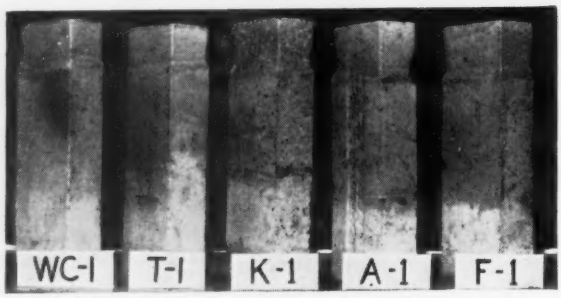

FIG. 4.—Class No. 2 refractory specimens after metaphosphate corrosion test.

Figures 3 to 7 are photographs of twenty-five different test specimens after the 66-hour corrosion test. Figure 8 illustrates the four different types of corrosion on the submerged ends of the test brick given in the last column of Table III. Figures 9 to 14 show photomicrographs of thin sections taken from the test ends of six refractories after the test. Figures 15 and 16 are

TABLE II

RESULTS OF 66-HOUR METAPHOSPHATE CORROSION TESTS ON VARIOUS TYPES OF REFRACTORIES

Lab. No.	Run No.	Immersion depth (in.)	Immersed end (gm.)	Weight loss during test (gm.)	Vol. of immersed end (cc.)	Vol. loss during test (cc.)	Weight loss (%)	Vol. loss (%)	Refractory
TZ-1[1]	13	2.50	1572	36**	470	16**	2.3**	3.4**	Zircon
Z-4	9	2.62	1555	50**	476	0	3.2**	0.0	"
CT-1[2]	11	3.06	1920	11	564	5**	0.6	0.9**	"
L-1	11	3.00	1907	22	561	5**	1.2**	0.9**	"
L-2	12	2.88	1804	1	535	22	0.0	4.1	
						Avg.	0.6**	1.6	
W-1*	14	2.25	865	32	395	40**	3.7	10.1**	Firebrick†
WC-1	14	2.25	815	15	388	17	1.9	4.4	Cast flux
T-1	14	2.19	886	44	394	9	5.0	2.3	Firebrick†
K-1	10	2.75	1118	5	494	27	0.5	5.5	Firebrick‡
A-1	10	2.75	1100	52	482	28	4.7	5.8	Firebrick†
F-1	10	2.75	1040	5	508	40	0.5	7.9	Cast glass
P-3	6	2.88	1190	90	540	45	7.6	8.3	" "
G-3	11	3.06	1266	14	551	16	1.1	2.9	Firebrick‡
G-4	12	2.69	1105	59	490	74	5.3	15.1	
						Avg.	3.2	9.0	
KA-1	12	2.75	1088	101	502	12	9.3	2.4	Firebrick†
HG-1	7	2.88	1130	93	515	60	8.2	11.6	"
HG-2	7	2.88	1150	105	518	45	9.1	8.7	
						Avg.	8.6	10.1	
E-3	6	3.00	1255	90	533	55	7.2	10.3	"
E-4	7	2.81	1165	80	493	55	6.9	11.1	
E-5	7	2.81	1170	90	493	45	7.7	9.1	
						Avg.	7.3	10.2	
C-3	6	3.00	1580	110	536	57	7.0	10.6	Electrocast
C-5	9	2.69	1480	160	495	62	10.8	12.5	
						Avg.	8.9	11.5	
WS-2	9	2.68	1095	70	500	60	6.4	12.0	Firebrick†
CR-1	10	2.50	1105	50**	490	60	4.5**	12.2	Firebrick‡
CN-1	14	2.13	1340	168	394	52	12.5	13.2	Electrocast
WT-2	9	2.69	1080	95	488	65	8.8	13.3	Firebrick†
NA-1	12	2.88	1174	143	530	72	12.2	13.6	"
X-3	6	3.00	1475	110	573	80	7.5	14.0	Firebrick‡
CZ-1	11	3.06	1585	252	573	95	15.9	16.8	Zircon†
ML-1	13	2.50	1387	207	443	88	14.9	19.9	Fused cast
MK-1	13	2.44	1329	274	435	132	20.6	30.4	" "
MH-1[3]	13	2.50	994	994	445	445	100.0	100.0	" "

* Brick expanded during test.
† Stiff-mud.
‡ Dry press.
** Indicates gain in weight or volume.

[1] Burners shut off 15 minutes during run No. 13 to be cleaned; temperature dropped to 970°C.
[2] Brick CT-1 in run No. 11 contained SiC which reduced some of the metaphosphate; slag viscous.
[3] Brick corroded away after 16 hr.

different views of the refractory lining of the plant metaphosphate furnace after (approximately) $2^1/_2$ months of service. Figure 17 shows suspended-arch zircon brick after $2^1/_2$ months of service.

IV. Discussion

Duplicate tests were made on the different brands of refractories listed in Table II to obtain some idea of the reproducibility of results. Duplicate brick, in some cases, were also tested in the same run but in opposite positions in the furnace; in other cases, duplicate tests were made in different runs.

The duplicate tests on test brick HG-1 and HG-2; E-3, E-4, and E-5; and C-3 and C-5 show a variation of approximately 10% from the average weight or volume loss (except for the weight losses of refractories C-3 and C-5). The latter showed larger variations (20%) in weight loss owing to the pipes or voids formed during their fabrication. Duplicate tests on test brick G-3 and G-4 varied widely; during the test on brick G-3 (run 11), the metaphosphate was affected by the silicon carbide in refractory CZ-1, which was tested in the same run.

(1) Class No. 1 Refractories

Refractories of class No. 1 (Table III) were characterized by a shallow flux line that did not exceed a depth of $^1/_8$ in., and the wash in every case was quite smooth and uniform. The bottom ends showed fine to very fine honeycombing, similar to test brick F-1 and Z-4 (Fig. 8); test brick, TZ-1, was the only exception in this test.

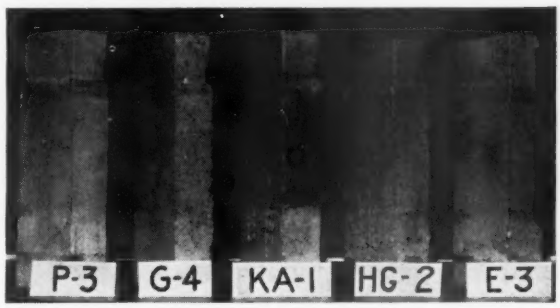

FIG. 5.—Class No. 3 refractory specimens after metaphosphate corrosion test.

The first four test brick were commercial grades of zircon refractories, which varied in composition from 86% of zircon ($ZrO_2 \cdot SiO_2$) for test brick L-1 to 94% of zircon for test brick Z-4. The zircon brick, as a whole, showed low weight and volume losses (Table II); in many cases, they showed a gain in weight or volume owing to the absorption of metaphosphate or to a small

TABLE III

SUMMARY OF RELATIVE RESISTANCE OF REFRACTORIES TO 66-HOUR METAPHOSPHATE CORROSION TEST[1]

Lab. No.	Kind of refractory	Maximum vol. or wt. loss (%)	Flux line depth (in.)	Kind of wash	Bottom end (honeycombing)
			Class No. 1		
TZ-1	Zircon	2.3[2]	$^3/_{32}$–$^1/_8$	Smooth	Medium
Z-4	"	0.0	$^1/_8$	Very smooth	Fine
CT-1	"	0.6	$^1/_{16}$–$^1/_8$	" "	Very fine
L-1-2	"	1.6	$^1/_{16}$–$^1/_8$	" "	Fine
W-1	Firebrick†	3.7	$^1/_8$	" "	Very fine
			Class No. 2		
WC-1	Cast flux	4.4	$^1/_8$	Very smooth	Very fine
T-1	Firebrick†	5.0	$^1/_8$	Smooth	Fine
K-1	Firebrick‡	5.5	$^1/_8$–$^5/_{32}$	Rough[3]	Coarse
A-1	Firebrick†	5.8	$^3/_{16}$	Moderately smooth	Fine
F-1	Vacuum cast	7.9	$^1/_8$	Very smooth	Very fine
			Class No. 3		
P-3	Wet cast	8.3	$^5/_{32}$	Moderately smooth	Fine
G-3-4	Firebrick‡	9.0	$^5/_{32}$–$^1/_4$	Rough[3]	Coarse interconnecting
KA-1	Firebrick†	9.3	$^3/_{16}$–$^1/_4$	Smooth	Fine
HG-1-2	"	10.1	$^1/_8$	Moderately smooth	Coarse
E-3-4-5	"	10.2	$^3/_{16}$	" "	Fine
C-3-5	Electrocast	11.5	$^1/_4$–$^5/_{16}$	Smooth	Coarse
WS-2	Firebrick†	12.0	$^1/_4$	Rough	Coarse interconnecting
			Class No. 4		
CR-1	Firebrick‡	12.2	$^1/_4$	Moderately smooth	Coarse
CN-1	Electrocast (special)	13.2	$^1/_4$	Smooth	"
WT-2	Firebrick†	13.3	$^1/_4$	Moderately smooth	Coarse interconnecting
NA-1	"	13.6	$^1/_8$–$^1/_4$	Smooth	Fine
X-3	Firebrick‡	14.0	$^5/_{16}$	Rough[3]	Coarse
			Class No. 5		
CZ-1	Zircon	16.6	$^3/_{16}$–$^1/_2$	Rough[3]	Fine
ML-1	Fused cast	19.9	$^1/_8$–$^1/_4$	Smooth	Medium
MK-1	" "	30.4	$^3/_{16}$–$^1/_4$	"	Coarse
MH-1	" "	100.0		Corroded off after 16 hr.	"

† Stiff-mud.
‡ Dry press.
[1] Brick arranged in order of decreasing resistance based on maximum average volume or weight loss of refractory.
[2] Gain in weight or volume.
[3] Coarse protruding particles on sides and bottom.

volume expansion during the test. Although zircon brick, TZ-1, showed the smallest loss of the four brands tested, Z-4, CT-1, and L-1 had the smoothest wash on the submerged ends. There seems to be no definite relation between corrosion loss and percentage of porosity between the zircon refractories; brick TZ-1 had the lowest porosity (17.2%) and brick Z-4 had the highest porosity (27.3%).

A thin section was made from the corroded end of zircon brick Z-4 (Fig. 9). A microscopic examination of the section indicated that the metaphosphate had penetrated between the grains of zircon without showing any appreciable reaction and without forming any compounds that could be identified.

The four brands of zircon brick have been used either as secondary pyrometer protection blocks or as a protective facing in the metaphosphate furnace, and all

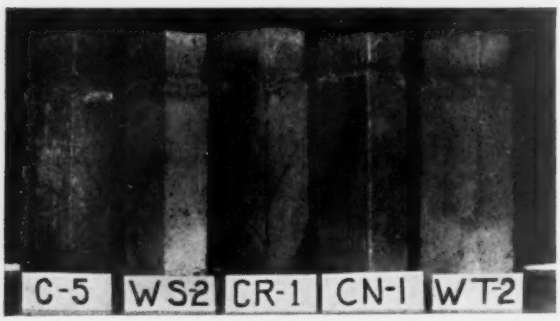

FIG. 6.—Classes No. 3 and No. 4 refractory specimens after metaphosphate corrosion test.

FIG. 7.—Classes No. 4 and No. 5 refractory specimens after metaphosphate corrosion test.

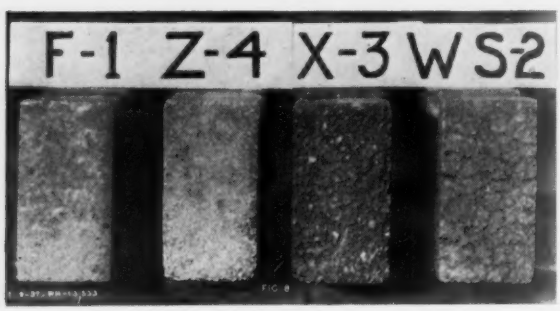

FIG. 8.—Submerged ends of refractory specimens after metaphosphate corrosion test

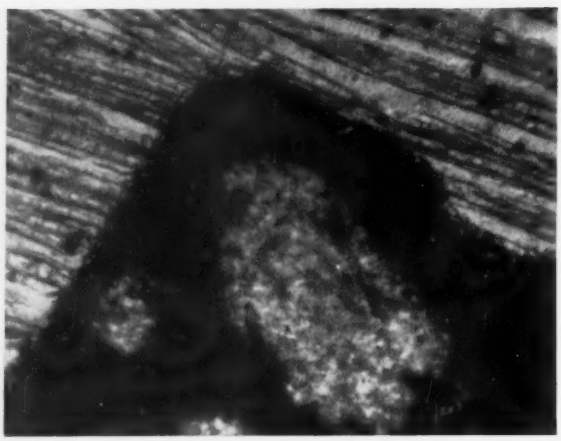

FIG. 9.—Thin section of zircon brick Z-4 below slag line; upper half shows fibrous metaphosphate crystals; lower half shows rounded zircon grains; 200×.

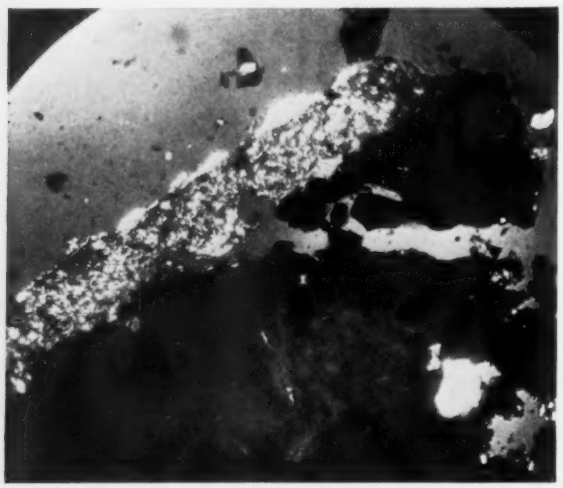

FIG. 10.—Thin section of glass refractory WC-1 below slag line, upper portion shows layer of crystalline metaphosphate attached to dark clay body with large quartz grain in lower right-hand corner; 50×.

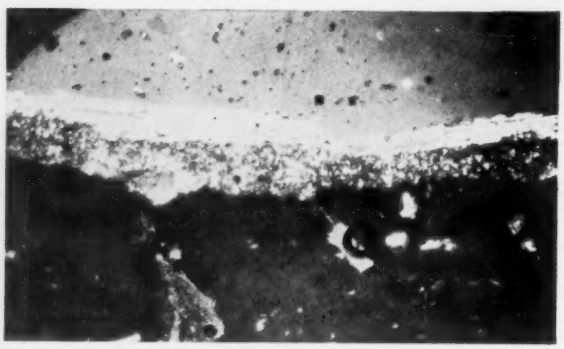

FIG. 11.—Thin section of fire-clay brick T-1 below slag line; upper, shows fibrous metaphosphate crystals; bottom, shows dark clay body with numerous pores and small quartz grains; 50×.

have shown high resistance to metaphosphate corrosion and erosion. The lower rock phosphate support of the plant metaphosphate furnace,[1(b)] in one case, was faced with 5 in. of zircon shapes over which the molten metaphosphate ran as it was formed in the upper part of the furnace shaft. This support gave service for more than 100 days of operation during which more than 300 tons of metaphosphate were produced. Figures 15 to 17 show zircon linings and brick after $2^1/_2$ months of service in the plant metaphosphate furnace; Fig. 15 shows a zircon dam and the zircon facing in the working end of the furnace where the molten metaphosphate collected before it was tapped; Fig. 16 shows a suspended zircon arch located between the combustion and reaction chambers, which was subjected to hot P_2O_5 gases and erosion from metaphosphate; Fig. 17 shows different views of the suspended-arch zircon shapes that were removed from the upper reaction chamber.

The other brick, W-1, of this class, a moderate heat-duty stiff-mud refractory with a fairly high silica content, showed over twice the corrosion loss of any of the zircon brick. It had a slightly higher resistance to corrosion, however, than the other firebrick types and a very smooth end wash; the wash below the flux line was greater than for the zircon brick. Considerable care would have to be exercised in the use of this brick in a plant furnace because it showed excessive volume expansion after the test (Table II); it also showed one of the lowest porosity ratings, 9.8%, of the stiff-mud type of refractories.

(2) Class No. 2 Refractories

The refractories of class No. 2 after the test, shown in Fig. 4, are composed of vacuum-cast glass refractories (WC-1 and F-1), an intermediate heat-duty stiff-mud brick (T-1), a double-fired superduty firebrick (K-1), and a high heat-duty stiff-mud brick (A-1). All of the refractories (except K-1) had a fairly smooth wash below the flux line (see Fig. 4). Brick K-1 had rough particles of grog protruding from the surface, and the end wash was similar to X-3 shown in Fig. 8; the end wash on the other specimens was similar to that of F-1 and Z-4 (Fig. 8). The attack below the flux line in every case was more pronounced than that for brick of class No. 1. Firebrick T-1, K-1, and A-1 had a lower porosity than those of the two glass refractories, WC-1 and F-1. The high silica (more than 65%) glass refractories, however, had a homogeneous body structure with fairly evenly distributed closed pores which tended to give a smooth glass attack on the submerged end.

Refractory brick, similar in composition to A-1, used in the large plant furnace, have shown greater resistance than other types of fire-clay refractories. The upper part of Fig. 16 shows the condition of stiff-mud brick after approximately $2^1/_2$ months of service in the plant furnace. Large size (12 by 18 by 24 in.) glass refractories, similar in composition to brick F-1, were used to line the bottom and portions of the side walls of the plant furnace. Although these large refractories showed numerous checks on the surface after $2^1/_2$ months of service (Figs. 15 and 16), they appeared to stand up well and showed the effect of a uniformly smooth surface attack.

Photomicrographs of thin sections of refractories WC-1, T-1, and F-1 taken below the slag line are shown in Figs. 10 to 12, respectively. The microscopic examination of the two glass refractories, WC-1 and F-1, showed a body composed of evenly distributed quartz grains bonded by clay with little penetration by the metaphosphate (shown clearly in Fig. 10). The stiff-mud brick, T-1, however, had numerous fissures near

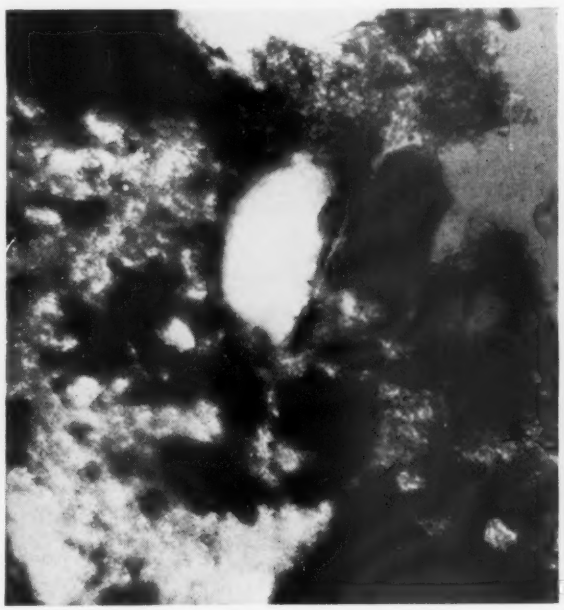

FIG. 12.—Thin section of glass refractory F-1 below slag line; upper right half shows quartz grains surrounded by metaphosphate crystals; dark portion is the clay body; 200×.

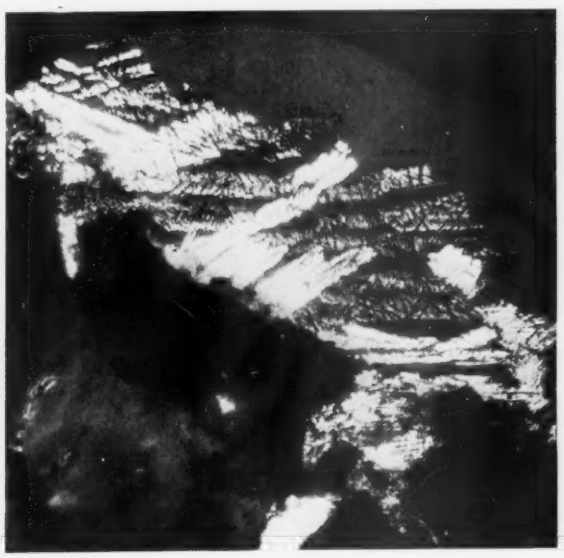

FIG. 13.—Thin section of firebrick G-4 below slag line; upper right shows fibrous metaphosphate crystals; lower left shows metaphosphate penetration in clay body; 50×.

the surface of contact into which the metaphosphate had penetrated (Fig. 11). The body also contained numerous uniformly distributed fine-grained quartz particles. No compounds formed from the reaction with metaphosphate could be distinguished.

(3) Class No. 3 Refractories

This group varied widely in physical and chemical properties and in the method of manufacture. As a class, it shows deeper flux lines than those of class No. 2, and the glass attack below the flux line is somewhat greater (Figs. 5 and 6). Test brick P-3, KA-1, HG-2, E-3, and C-5 have fairly smooth side washes, whereas G-4 and WS-2 show a rough wash and a coarse honeycombed end wash similar to WS-2 in Fig. 8.

Brick with the coarse end wash tend to become increasingly coarser when they are used in large furnaces, and they fail more rapidly at the joints than those that show smoother washes.

Brick HG-2, E-3, G-4 and C-5 have been used either in the large or small plant-scale metaphosphate furnaces. Test brick HG-2 were used to line the side walls, and C-5 were used in the bottom part of the combustion chamber of the plant furnace. These refractories were still in good condition after more than 100 days of operation. Special circle brick shapes, however, made from body HG-2, which supported the lower rock phosphate arch in the top of the combustion chamber, were badly cracked and eroded on the sides where the metaphosphate dripped from the upper arch. The G-4 refractories used to line the upper part of the phosphorus vaporizer were badly eroded at the joints and showed rough surfaces after 100 days of service.

The refractories in this class that appeared to be the most suitable for use in a metaphosphate furnace were the dense stiff-mud brick, KA-1, HG-2, and E-3, and the electrocast refractory, C-5.

Photomicrographs of thin sections taken from the submerged ends of refractories G-4 and WS-2 are shown in Figs. 13 and 14. Both sections show marked penetration of the metaphosphate into the fire-clay bodies.

FIG. 14.—Thin section of firebrick WS-2 below slag line; fibrous crystals are metaphosphate; dark portions are the clay body; extensive penetration by metaphosphate; 200×.

(4) Class No. 4 Refractories

Figures 6 and 7 show this class of test brick; brick CR-1 and X-3 are high-aluminous, dry-pressed refractories; CN-1 is an "electrocast" refractory containing approximately 23% of zirconium oxide; and WT-2 and NA-1 are high heat-duty, stiff-mud fire-clay brick. Their porosity varies from 2.4 to 24%.

All of these brick show a deep flux line of $^1/_4$ in. or greater, and the attack below the flux line is quite marked, which gives the brick a keystone shape when it is viewed from the edge (see NA-1, Fig. 7). All of the brick except NA-1 showed a coarse wash on the submerged end; brick X-3 also showed coarse protruding particles of grog on the sides. The metaphosphate apparently attacked the bond more readily than the coarse flint-clay particles. Although brick X-3 was quite dense and highly aluminous (67%), it did not resist corrosion so well as C-5, an "electrocast" refractory.

None of the brick of this class appeared to be suitable for the construction of metaphosphate furnaces.

FIG. 15.—Zircon refractories and flux block in plant metaphosphate furnace.

FIG. 16.—Zircon arch and stiff-mud brick in plant metaphosphate furnace.

(5) Class No. 5 Refractories

The first three brick of this class are shown in Fig. 7; brick CZ-1 is composed of a combination of zircon and silicon carbide, and ML-1, MK-1, and MH-1 are of variable composition (Table I), and were made by the fused casting method.

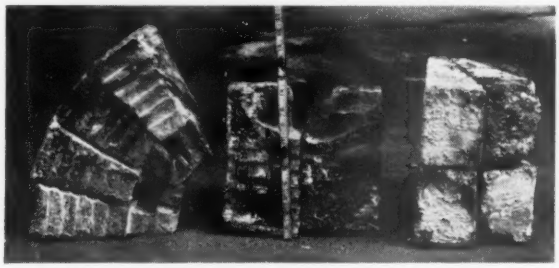

FIG. 17.—Zircon arch brick from plant metaphosphate furnace.

Brick CZ-1 contained approximately 22% of silicon carbide which apparently reduced the resistance of the zircon to metaphosphate corrosion. There was evidence during the test that the silicon carbide reduced the metaphosphate and liberated P_2O_5, which came off as a white smoke. The attack was quite severe below the flux line (Fig. 7).

Brick ML-1 showed the best resistance of this brand to corrosion. Although it contained approximately 93% of alumina, it did not resist the molten metaphosphate so well as C-5, which contained approximately 17.5% of silica and only 78% of alumina.

Brick MH-1 was corroded completely through at the flux line after testing for 16 hours. The analysis of this brick (Table I) shows that it contains large quantities of alkaline earth oxides (CaO and MgO) which are not resistant to the acidic metaphosphate. The results of a 17-hour corrosion test at 1300°C. on a magnesite brick (87% of MgO), made previous to these tests, showed that magnesite is rapidly attacked and that the submerged end of the test brick was cut off.

None of the brick in class No. 5 appeared to be suitable for use with molten metaphosphate.

V. Conclusions

(1) Refractories that contain more than 85% of zircon ($ZrO_2 \cdot SiO_2$) show the best resistance to metaphosphate in the 66-hour corrosion test, and there is little difference in corrosion resistance between different brands.

(2) Moderate heat-duty, stiff-mud refractories, such as T-1 and W-1 stiff-mud brick, show corrosion resistance equal to that of high heat-duty stiff-mud firebrick.

(3) High silica (more than 65% of SiO_2) glass refractories, made by the wet-vacuum casting process, (WS-2 and F-1) resist corrosion as well as the dense stiff-mud firebrick.

(4) The fire-clay refractories with the lowest apparent porosities have better resistance to metaphosphate corrosion than those of higher porosity.

(5) Fire-clay refractories with 40% or less of alumina appear to resist molten metaphosphate better than those of higher alumina content.

(6) The high-alumina mullite type of "electrocast" refractory (C-3) show higher resistance to corrosion than the high-aluminous diaspore type of firebrick.

(7) None of the fused-cast brands (MC-1, MK-1, or MH-1) show satisfactory resistance to metaphosphate corrosion. Of the three brands tested, ML-1 with approximately 93% of alumina gives the best results.

(8) The laboratory corrosion test results show good correlation with the service results obtained in the large plant furnace.

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DIES AND AUGERS*

BY J. H. ISENHOUR

ABSTRACT

The types of dies and augers best suited for most deaired clays are discussed. The relation between augers and dies and the causes of lamination and warped brick are pointed out.

I. Introduction

Dies on an auger machine are used to form the clay mass into the shape desired, and the augers convey and extrude the mass to and through the die.

Three factors must be considered in a study of dies, namely, (1) its purpose and function, (2) the type of clay, and (3) the construction of the die.

A material that is fairly plastic when it is deaired and that has a low drying shrinkage will not have defects from dies, but materials that are nonplastic and fine-grained and have a considerable amount of drying shrinkage show cracks and laminations from the dies.

A theory has been advanced that laminations, in deaired material might be increased by excessive pressure either from the die or from the auger. Contrary to this expectation, however, only in a few cases has a perfectly straight die worked to advantage on deaired clay for brick or for bulky ware.

With a straight die, the material must come down from a 16- or 12-in. auger to a 4- by 8-in. rectangular

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opening. The friction of deaired clay on clay is far greater than that of clay on metal, and a straight die does not have enough compression area to form a round slug from the auger into a homogeneous rectangular mass. Extending the length of a straight die would help, but unless the center of the mass could be cored enough to offset the outside friction, the column would not be balanced. A straight die, furthermore, usually requires more horsepower if it is cored because of the friction of clay between auger and die opening.

II. Taper Back of Die

Dense clay must be forced into a square opening from a round slug, and to avoid lamination, equal pressure or friction must be maintained throughout the mass. The round slug must be forced down gradually into a rectangular die, and the back of the die must therefore be tapered. The closer to the auger this taper starts, the less horsepower will be required. The degree of taper and the length of taper are dependent on the type of material, the size of the die opening, and the extent of the coring.

If the taper is too abrupt and too short, the material will slip on itself rather than on the metal, thus defeating its purpose; if the auger taper is too small, the column will not be properly formed.

The more nearly uniform in size are the back end of the former and the auger, the more uniform will be the pressure on all parts of the die and the greater the output at the auger point.

The length and taper of the shaper cap of a die depend chiefly on the degree of coring and effective lubrication, that is, the more taper on the die and the more the coring, the shorter the shaper. The amount of slope on the shaper should be enough to form perfect corners and fill out the ends.

In the manufacture of brick, the shaper must have a greater degree of slope if the brick are not cored; for hollow ware, if the die has good forming around the bridge work, the cores and shaper may be short and perfectly straight.

If the internal friction balances the outer friction, there should be no lamination. With less taper, the friction on any given section of the clay movement after it is formed from the auger will be less. In a hollow-tile die, the inner webs are easier to balance with the outer webs if the cores and the outer cap are straight. The length of the cores and of the outer cap is increased or decreased according to the size of the die and that of the core.

III. Brick and Liner Construction

On hollow-tile dies, there are three essential requirements in addition to the shape of the outside, namely, (1) the liners must be so designed that they may be changed easily from scored to smooth design and be easily replaced when worn, (2) the bridges and cores should offer the least possible resistance to the flow of material, and (3) the bridges and cores should be so constructed as to allow balancing of the dies. It is good practice to make them movable sidewise because a permanent bridge often requires lugs and drags to balance the flow. The bridges should be set far enough back in the former to allow the bulk of the material to flow around the bridges before it reaches the small part of the die throat. The farther back the bridge is set in the large part of the taper, the less horsepower will be required; the farther the bridges are set back from the cores, the stronger must be the boss connecting the cores to the bridge. A weak boss or weak bridge will cause the core to weave, and it is not possible to balance the die.

The simplest die to make and repair and the least expensive to build has an all-welded case of plate steel, $^5/_8$ to $^3/_4$ in. in size, and lined inside with hard alloy cast plates about $^3/_8$ in. thick.

The higher the degree of metal resistance to wear, the better will be the auger. All machines have about the same general design of augers, which has been developed by many years of trial and practice.

Not all of the lamination comes from the die; it may also be set up in the auger flights. Unequal pressure, caused by unequal densities (even in deaired material) when more pressure occurs in the auger than in the die, will result in auger lamination. The clay is loose when it starts in auger flights, and the farther it travels toward the die the more compact it becomes. Many plants have eliminated deairing losses by changing from a tapered to a straight auger point.

In many plants, part of the brick show cracks and shivers throughout the mass, but the same material on the same machine never shows these defects in hollow ware. This trouble is caused by too much pressure between the auger flights, especially where the double wing splits the flow from the single-wing part of the auger point. If any of the material does not shed readily from the flights, a back pressure will result and cause a temporary choke-up. Lamination from this cause occurs when the auger becomes slick, pitted, or badly worn.

To offset this flight-compression trouble, the pitch of the flights toward the auger point could be increased on some of the easy-flowing materials. With nonplastic shales, however, this adjustment of the flights was ineffective, and it failed on material used by the writer. The horsepower was increased about 30% on the auger machine to correct this difficulty.

Any increase in pitch will increase friction, and the material is unlikely to shed from the flights on the increased pitch. There is only one answer, that is, to keep the pitched auger flight as small as possible and to increase the diameter of the auger set gradually toward the direction of the die.

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RÉSUMÉ OF TECHNICAL STUDIES OF SALT GLAZING*

By H. D. Foster

Abstract

A résumé is given of the technical literature on salt glazing together with such conclusions as may be drawn. Attention is called to some of the deficiencies which are found in salt glazes.

I. Introduction

Salt glazing was used in Germany during the 16th century,[1] and the technique of its application to stoneware was highly developed in the Staffordshire district in England during the 18th century.[2] With the development and use of sewer pipe, the salt-glazing process was applied extensively in Europe and America. Many problems were encountered which led to several technical investigations.

Salt glazing has been applied more recently to building brick and tile intended for use in the interior walls of laboratories, shops, schools, and hospitals. The smoothness of the surface, the color, and the solubility of these products have been studied, but certain other problems, especially crazing, have not been solved.

An investigation of the causes of crazing and the development of a noncrazing glaze has been planned. As a basis for this proposed investigation, a survey has been made of the literature on the general subject of salt glazing. Some of the articles that were studied are outstanding research reports which contain pertinent information that has been summarized in this paper.

II. Body and Glaze Compositions and Salt-Glazing Temperatures

Attempts to relate the temperature of salt glazing, the composition of the body, and the composition of the glaze were made by Barringer,[3] Mackler,[4] and Berdel,[5] who worked on the assumption that the reactions in salt glazing consist of the vaporization of sodium chloride and the double decomposition of salt and water vapor to form Na_2O and HCl. The HCl passes off readily with the combustion gases, whereas the Na_2O tends to remain in the kiln and, coming into contact with the surface of the clay pieces, reacts to form a sodium-aluminum-silicate glass.

The success of salt glazing was also thought to depend on the ratio of alumina to silica in the body. Tests therefore were made by salting trial bodies with various alumina-silica ratios. Salting temperatures of 1100°, 1200°, and 1300°C. (2012°, 2192°, and 2372°F.) were used and were found to be satisfactory. Good glazes were obtained at these temperatures on clay bodies with alumina-silica ratios ranging from 1 : 3.3 to 1 : 12.6.

It is difficult to obtain the composition of a salt glaze because such glazes usually average about 0.02 in. thick (seldom as much as 0.05 in.). The molecular formula given by Barringer is as follows:

$$\left.\begin{matrix} Na_2O\ 1.326 \\ K_2O\ 0.003 \\ CaO\ 0.297 \\ MgO\ 0.003 \\ FeO\ 0.073 \end{matrix}\right\} Al_2O_3\ 1.00 \quad SiO_2\ 4.418$$

He obtained the sample for his analysis from beads that had formed from the mobile glaze. They were chipped from the surface of the sewer pipe and were freed from the visible body before they were pulverized in preparation for the chemical analysis.

Mackler concluded from some synthetic experiments that the glaze composition could vary from Na_2O 1.00, Al_2O_3 1.0, and SiO_2 5.5 to Na_2O 1.00, Al_2O_3 0.5, and SiO_2 2.8.

The limits of the glaze composition were checked later by Neumann and Fischer,[6] who considered the process of formation of the glaze, its composition, its structure in relation to certain deficiencies, and its chemical resistance. They acknowledged the presence in the glaze of minor portions of iron, alkaline earths, and alkalis other than sodium, and they assumed the three principal constituents to be Na_2O, Al_2O_3, and SiO_2. On this assumption, they compounded about eighty different mixtures of the three components, and they melted or attempted to melt them in small, unglazed porcelain crucibles. They found that certain of these mixtures made clear glasses and could be called glazes. The glasses that fell in the salt-glaze classification agreed with Mackler's conclusion that the glaze composition approximates Na_2O 1.0, Al_2O_3 0.5, and SiO_2 2.8.

III. Effect of Minor Body Constituents

The part which the iron, lime, alumina, and silica

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 2, 1941 (Structural Clay Products Division). Received April 2, 1941.

[1] (*a*) "Salt Glaze," *China, Glass, & Lamps*, **56** [8] 39 (1937); *Ceram. Abs.*, **16** [9] 279 (1937).
(*b*) Kalf, *Tonind.-Ztg.*, p. 1299 (1899).

[2] (*a*) W. B. Honey, "English Salt-Glazed Stoneware," *Trans. English Ceram. Circle*, No. 1, pp. 12–22 (1933); *Ceram. Abs.*, **14** [8] 179 (1935).
(*b*) C. L. Avery, "English Salt Glaze," *Bull. Met. Mus. Art*, **30** [3] 53–59 (1935); *Ceram. Abs.*, **14** [8] 179 (1935).

[3] L. E. Barringer, "Relation Between Constitution of Clay and Its Ability to Take a Good Salt Glaze," *Trans. Amer. Ceram. Soc.*, **4**, 211–29 (1902); p. 222.

[4] Mackler, *Tonind.-Ztg.*, **251**, 440 (1905).

[5] Berdel, *Sprechsaal*, **45**, Nos. 30 and 36 (1912).

[6] (*a*) Bernhard Neumann and Werner Fischer, "Salt Glaze," *ibid.*, **60** [17] 294–97; [18] 314–17; [19] 331–34; [20] 349–52 (1927); *Ceram. Abs.*, **6** [12] 586 (1927).
(*b*) Bernhard Neumann, "Salt Glaze," *Sprechsaal*, **62** [36] 653–55; [37] 673–76 (1929); *Ceram. Abs.*, **8** [12] 899 (1929); II, *Sprechsaal*, **62** [42] 767–70; [43] 787–89 (1929); *Ceram. Abs.*, **9** [1] 48 (1930); *Sprechsaal*, **62**, pp. 872, 887 (1929).

content of the body plays was studied by Brick,[7] Riddle and Gladding,[8] Schurecht,[9] and Hursh and Clemens.[10] The experimental work of these investigators was carried out by glazing compounded bodies. Neumann and Fischer[6] studied the action of sodium chloride and water vapor on each of the components, and found that the Na_2O reacted with all of the components, but more especially with the alumina and silica.

IV. Process of Glaze Formation

Neumann and Fischer[6] state that for successful salt glazing (*a*) the temperature must be high enough (1100° to 1300°C.) to prevent the condensation of the sodium vapor until it can react and combine with the body and (*b*) the body must be vitrified or at least fired high enough to have an appreciable amount of the glassy phase. If the body is porous, the fluid salt glaze ordinarily formed on the surface will be absorbed into the pores. A thorough glaze covering on such bodies would require often-repeated saltings.

When the body is ready for salting, its surface is made up of a network of glass in which undissolved substances are embedded. The Na_2O reacts readily with the glassy body surface to give a less viscous glass. Reaction takes place with the undissolved substances at the same time, but a greater amount of Na_2O is required to form a glass with low viscosity. Further and continued reaction takes place at the surface of the glaze already formed. This formed glaze likewise attacks and dissolves the surface of the clay body. Thus the entire glaze in time will become homogeneous if the necessary high temperature is maintained for a sufficiently long period.

If the original fired body surface is rough, as from a coarse-textured body, the glaze will be rough and will have an uneven texture. Sewer-pipe bodies have a coarse texture, and the glazes are usually uneven. The clay used for structural building units generally is ground much finer, and a smooth glaze therefore results.

V. Other Causes of Glaze Unevenness

Neumann and Fischer describe and discuss an additional cause for glaze unevenness as follows: "Light- and dark-colored portions of glaze are sometimes found side by side. The glaze is thick at the dark positions. At the light-colored positions, the glaze is depressed and so thin that the body often shows through the glaze. Frequently small round holes are found in these depressions.

"The holes are caused by the gas bubbles coming from the body which break through during the formation of the glaze. If the glaze is viscous, the gas bubble, in breaking through, leaves a crater which may be only partially refilled. If the glaze has cooled sufficiently to form a surface skin, the gas coming from the body will raise whole areas of glaze away from the body. When the gas finally does escape, the raised portion of glaze will settle back and congeal into a wrinkled and rough surface having in it holes or craters through which the gas has escaped. Such surfaces can be smoothed out only by reheating at a higher temperature."

Neumann and Fischer also state that the gases originate in and escape from clay bodies even up to the end of firing. They believe that the roughness of the glaze is caused by carbon monoxide, which originates from amorphous carbon deposited in the pores before the start of the salting operation. They suggest that strong oxidizing conditions be maintained for a considerable time just before and even during the first light salting.

VI. Glaze Resistance

Neumann and Fischer also made an extensive study of the resistance of the glaze to chemical attack. They first subjected glaze surfaces to the action of HCl. Then, in connection with their study of glaze compositions, during which they had made glasses of various proportions of Na_2O, Al_2O_3, and SiO_2, they subjected the various glazes to the attack of HCl and found that the chemical resistance decreased with an increase of Na_2O.

From the nature of the formation of glazes as previously shown, the thicker glazes would be expected to have the greater concentrations of Na_2O on the surface. Glazes which are made at the higher temperatures also become less viscous and can become more homogeneous, that is, the Na_2O concentrations in the surface of the glaze are lower than in glazes formed at lower temperatures. Inasmuch as chemical resistance decreases with an increase of Na_2O and the attack is always on the glaze surface, the thinner glazes and those formed at the higher temperatures may be expected to be the most resistant to attack.

VII. Possible Reduction of Glazing Temperature

The foremost question in the minds of the manufacturers is the possibility of obtaining a salt glaze at a lower temperature. Engobes may be applied to the clay body before it is dry, and colorants may be included in these engobes.[11] The surface of the green

[7] Brick, *Tonind-Ztg.*, p. 1923 (1901).

[8] F. H. Riddle and A. L. Gladding, "Time-Temperature Curves During Salting of Some Oil-Fired Sewer-Pipe Kilns," *Trans. Amer. Ceram. Soc.*, **17**, 314–22 (1915).

[9] (*a*) H. G. Schurecht, "Clay Sewer-Pipe Manufacture, II," *Jour. Amer. Ceram. Soc.*, **6** [6] 717–29 (1923); (*b*) IV, *ibid.*, **7** [6] 411–22 (1924).

[10] R. K. Hursh and E. C. Clemens, "Effects of Body Composition and Firing Treatment on Salt Glazes," *ibid.*, **14** [7] 482–89 (1931).

[11] (*a*) P. E. Cox, "Processing Clays for Colors and Surface Effects," *Brick & Clay Record*, **95** [1] 27–29 (1939); *Ceram. Abs.*, **19** [10] 237 (1940).

(*b*) H. F. Dingledine, "Salt-Glazing Clay of Low Vitrifying Temperature," *Jour. Amer. Ceram. Soc.*, **15** [1] 82–83 (1932).

(*c*) J. O. Everhart, "Salt Glazing Ceramic Products," *Brick & Clay Record*, **75** [8] 480 (1929); *Ceram. Abs.*, **8** [12] 883 (1929).

(*d*) A. E. Buch, "Improvement of Clayware by Coating with Engobe," *Tonind.-Ztg.*, **54** [31] 526–27 (1930); *Ceram. Abs.*, **9** [7] 527 (1930).

(*e*) J. O. Everhart, "Production of Salt Glaze by Application of Slip to Ware," *Jour. Amer. Ceram. Soc.*, **13** [6] 399–403 (1930).

(*f*) S. H. Ivery, "Method of Salt Glazing Brick and Other Clay Products," U. S. Pat. 1,735,167, Nov. 12, 1929; *Ceram. Abs.*, **9** [1] 38 (1930).

body may also be treated with an energizing medium of soluble salts sprayed on the body.[12] The present study, however, is concerned with glaze formations on the untreated body caused by admixtures with, or total replacement of, the NaCl by other volatile salts.

The use of KCl in place of NaCl was tried by Neumann and Fischer, who found that KCl will cause a reaction to take place at a lower temperature than with NaCl but that the potassium glaze is so viscous that the reaction is limited. These investigators also tried MgCl and CaCl but with no success.

The most complete study of the use of salts other than NaCl or of mixtures of various chlorides has been carried out by Schuen.[13] Nearly all of the mixtures had such a low melting point and the melted mass was so fluid that it ran away before a temperature high enough for vaporization and decomposition could be attained. The molten salt mixtures, however, were very corrosive. Mixtures of equal parts of sodium chloride and calcium chloride corroded the ware badly. When sodium chloride-magnesium chloride mixtures were used, the corrosive action was similar but not so bad as with the calcium chloride. When sodium chloride-potassium chloride mixtures were used, vaporization and decomposition occurred, but only a slight amount of glaze was formed. When sodium chloride-lithium chloride mixtures were used, however, a good but thin glaze was formed.

Schurecht[14] also used potassium chloride as a salt-glazing material and was apparently more successful than Schuen.

Schuen also tried equal mixtures of sodium chloride with lithium chloride, cerium chloride, manganese chloride, and iron chloride. He obtained good glazes with all of these mixtures.

There are certain objections, however, to the use of each of these materials. The cost of lithium chloride is prohibitive for use on ordinary commercial ware. Although glazes made with mixtures of sodium chloride and cerium chloride are extra thick, they have a yellow tint as though they were contaminated with lime. Manganese chloride or iron chloride cannot be used to obtain a clear, colorless glaze.

The use of borax as a partial replacement of sodium chloride has been practiced by some American manufacturers.[15] The addition of borax during the first part of the salting or as a mixture with sodium chloride will give a glaze with a high gloss. These same manufacturers state that lower temperatures are required if borax is used, but they do not substantiate their claim.

VIII. Crazing of Salt Glazes

Crazing, the most outstanding deficiency in salt glazes, has not been studied by any of the investigators of the technique of salt glazing. It has been claimed that glazes formed with lithium chloride will not craze,[16] but no such definite claims have been made for any of the other salt-glaze materials. Some of the manufacturers who use borax suggest that it will reduce the danger of crazing.

A proposed investigation of salt glazing for use on structural brick and tile, on the basis of these suggestions, will cover chiefly the study of glazes made of mixtures of sodium chloride, borax, and lithium chloride to promote the development of a noncrazing salt glaze.

IX. Summary

The technical information on salt glazing given in the literature may be summarized as follows:

(1) A good salt glaze may be obtained with sodium chloride on clay bodies that have an alumina-silica ratio of 1:3.3 to 1:12.6 and that mature at temperatures ranging from 1100° to 1300°C. (2012° to 2372°F.).

(2) The composition of salt glazes varies from Na_2O 1.0, Al_2O_3 1.0, and SiO_2 5.5 to Na_2O 1.0, Al_2O_3 0.50, and SiO_2 2.8; the higher portions of Na_2O are on the surface or in the thicker glazes.

(3) The smoothness of the glaze is directly related to the texture of the clay body. Gases coming from the body during the salting operation can also cause roughened and uneven glazes.

(4) The chemical resistance of the glaze decreases with an increase in the content of Na_2O. It follows that the glazes formed at the higher temperatures as well as the thinner glazes are the most resistant.

(5) The use of KCl, CaCl, and MgCl with NaCl will not give so good a glaze at the same or lower temperatures as those required for pure NaCl.

(6) It has been claimed but not substantiated that the use of LiCl and of borax will give a glaze less susceptible to crazing.

(7) The most permanent salt glazes are obtained at the higher temperatures and the less permanent ones at the lower temperatures.

Engineering Experiment Station
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[12] Orqualin, "Glazing Ceramic Bodies," Ger. Pat. 432,724, Dec. 5, 1923; *Ceram. Abs.*, **6** [6] 230 (1927).

[13] W. Schuen, "Vitrified Brick and Salt Glaze," *Tonind.-Ztg.*, **63** [31] 357–59 (1939); p. 358; *Ceram. Abs.*, **19** [4] 92 (1940).

[14] H. G. Schurecht, "Salt Glazing," U. S. Pat. 1,583,902, May 11, 1926; *Ceram. Abs.*, **5** [7] 216 (1926).

[15] (*a*) Singer, Ceramic Glazes. Pacific Coast Borax Company.

(*b*) "Borax-Salt Mixture Improves Appearance of Salt-Glazed Ware," *Brick & Clay Record*, **95** [1] 30 (July, 1939); *Ceram. Abs.*, **19** [10] 236 (1940).

[16] G. A. Bole, private communication.

ADJUSTABLE RECIRCULATING HUMIDITY DRIER*

By T. W. Garve

Abstract

A tunnel drier has been designed that permits the recirculation of humidity in varying amounts or, by operating one damper, no recirculation. The intake flue is located near the middle rather than at the end of the drier.

I. Introduction

A drier has been designed for tender drying clays or for ware that requires careful drying. The deairing process has made possible the use of clays for brick manufacture that were formerly unsuitable, and other clays, formerly used only for brick, may now be used for hollow ware.

This drier design eliminates many drying difficulties because any portion of the humidity in the exhaust may be returned to the drier with the waste heat from the kilns, heat from steam coils, or from any other source. The drier may be operated entirely without humidity return so that it may be used alternately for tile and brick.

II. Adjusting Drier

If the vapor damper is in its highest position (Fig. 1), no vapor passes to the stack; all of the vapor, however, passes through the "return flue" to the drier. Small amounts of vapor may escape, but the bulk may be returned to the drier if a narrow gap is left between the damper edge and the ceiling of the flue. If the damper is in its horizontal position, most of the vapor will pass out through the stack and some will return to the drier; this condition may be emphasized by lowering the damper still more. With the damper in its lowest position, the return flue becomes sealed, and the vapor stack will handle all of the exhaust as in any regular drier installation.

The outside air inlet at the end of the exhaust flue would not be needed in the application of waste heat from the kilns, but it could serve as a tempered air supply to a coil heater; otherwise, it may be used as a manhole and would be covered when not in use.

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 1, 1941 (Structural Clay Products Division). Received March 20, 1941.

Another improvement in this design is the location of the intake flue, which is placed near the middle of the drier instead of at the end. Air normally blown into a duct will go to the end of the duct and will build up a pressure before it passes out through branches or orifices in any great degree. The greatest pressure intensity is normally developed at the extreme ends of the ducts or near the hot end of the drier where all drying must be completed. The movement of air through a horizontal duct and into cross ducts or restricted outlets depends on the frictional resistance of the duct walls and the inertia of the air to follow a straight path. Whenever any cross duct or restricted outlet in the series offers more resistance, there is no movement in these cross ducts or through the outlets. The normal straight draft intensity will therefore be greater at the hot end of the drier and will diminish along the tunnel toward the colder end from where the ware is advancing.

The floor openings are covered with flanged steel plates which may be moved inward or outward to change the size of the slot. The plates extend to the height of the car axles, thus delivering the air somewhat under nozzle pressure closer to the bottom of the car. A downward adjustment may also be made by building the duct walls out of brick and by lowering the plates to the thickness of a brick or split brick. This may be done toward the colder end where greater caution is needed, although it would be simpler to move one plate slightly inward and thus narrow the slot. This principle of introducing the air closer to the bottom of the car results in drying the ware in the center of the car before that on the outside is dry.

In this design, the fan location has the additional advantage of a shorter return drier flue than if the fan were located at the hot end.

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Columbus, Ohio

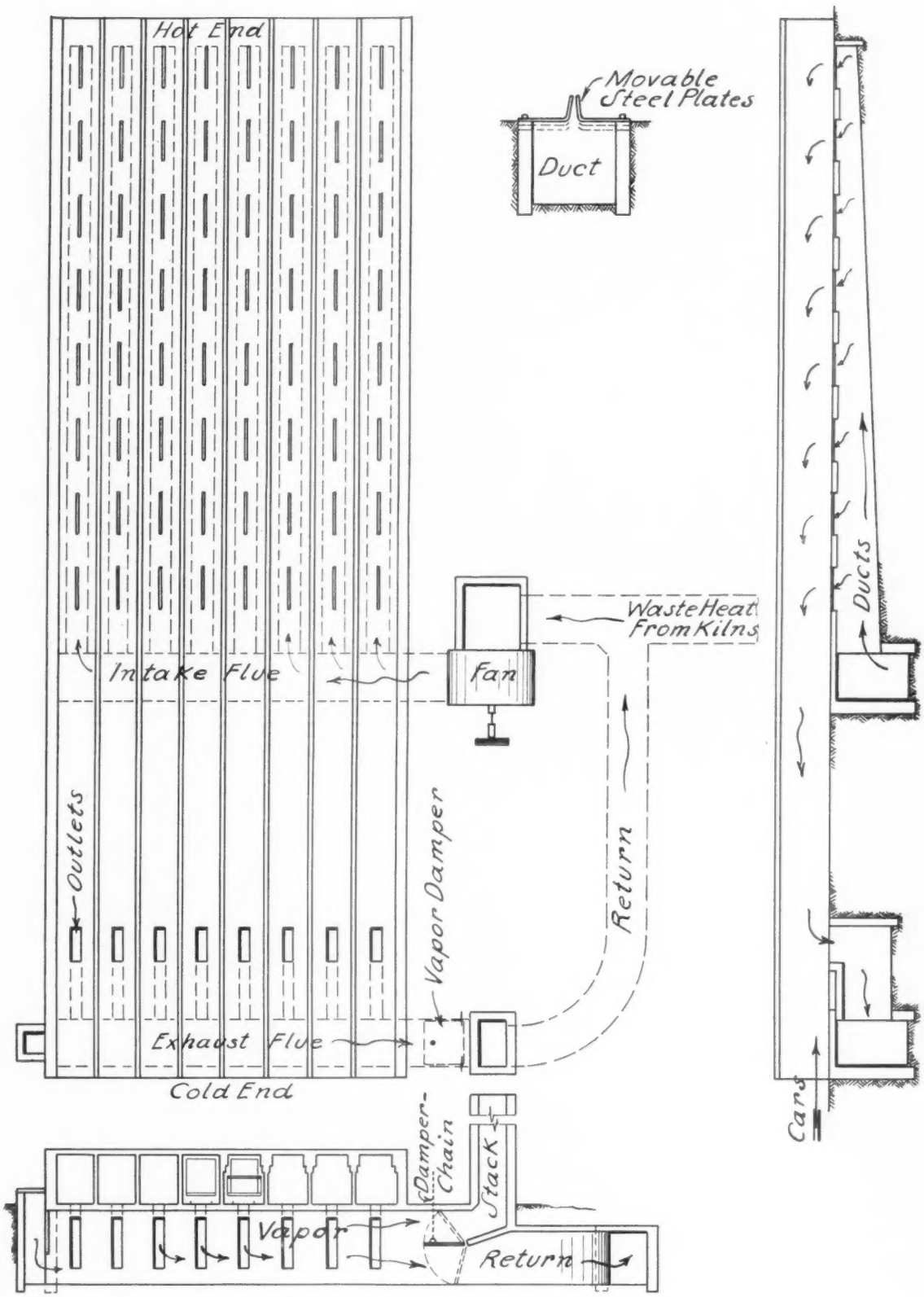
Hot End
Movable Steel Plates
Duct
Ducts
Waste Heat From Kilns
Intake Flue
Fan
Outlets
Vapor Damper
Return
Exhaust Flue
Cold End
Cars
Damper-Chain
Stack
Vapor
Return

FIG. 1.

DISCUSSION ON ELECTROPHORETIC DEWATERING OF CLAY SUSPENSIONS*

By Sidney Speil

Abstract

Studies on the electrophoretic behavior of Tennessee ball clay have been made with the use of a simple stationary electrode apparatus. Data were obtained on the effect of the amount and type of electrolyte, hydrogen-ion concentration, type of electrode, potential gradient, electrode separation, time of deposition, solids concentration, and temperature of the suspension. The effect of these variables on energy consumption, rate of deposition, and moisture content of the deposit is shown.

I. Introduction

The pioneer work of Count von Schwerin in Germany on electrical methods of dewatering clay led to the development of the rotating-anode electrophoresis machine now used in several kaolin refineries in Germany and Czechoslovakia. After Bleininger's work at the Bureau of Standards in 1915, Curtis[1] published data on the electrophoretic dewatering of a Washington kaolin using a rotating-anode machine. Hall[2] and Wilcox[3] did similar work with cement slurries. Other writers have described the Zettlitz kaolin operations and have mentioned a power consumption ranging from 20 to 80 kw.-hr. per ton of dry clay and a moisture content of 35% in the deposited clay.

The more colloidal a clay, the more pronounced are its electrical characteristics. Many of the ball clays that are so difficult to filter-press should therefore lend themselves admirably to the electrical method of dewatering. The effectiveness of such a process depends on many variables, such as (1) the orientation of electrodes, (2) the time of deposition, (3) the temperature of the suspension, (4) the density of the current, (5) the concentration of solids in suspension, (6) the pH of the suspension, (7) the type of electrolyte, (8) the spacing of electrodes, and (9) the type of electrode.

To study the effect of any one variable, the others must be standardized during a set of experiments. Stationary electrodes were adopted for this preliminary study to simplify the experimental technique, although any commercial installation necessarily would be continuous. The relative effect of any factor should be the same with larger quantities under similar control, although the numerical values may differ considerably.

II. Experimental Apparatus

Two vertical 5- by 5-in. zinc electrodes were supported at a definite spacing in a 4-gallon leucite container. The suspension was circulated continuously between the container and a 10-gallon reservoir to minimize variations in pH, the concentration of the solids, and the temperature. The standard experimental conditions were (*a*) 1 amp. per square decimeter, (*b*) 19% of solids in suspension, (*c*) 20° to 22°C., (*d*) 10 minutes of deposition time, and (*e*) vertical zinc electrodes with 1-in. spacing. Only one condition was varied during any series of experiments.

The requirements for an efficient electrical dewatering method are low energy consumption, a high rate of deposition, and a low moisture content of the deposit. The effect of the experimental variables on these three derived functions is discussed.

III. Orientation of Electrodes

A change from vertical to horizontal electrodes with downward migration cut the consumption of energy in half under some conditions. At the same time, the rate of deposition increased, and the moisture content decreased. With horizontal electrodes, electrophoretic migration is aided by gravity sedimentation and by electrical precipitation (electrodecantation). Vertical electrodes were adopted for further work to eliminate these effects.

IV. Time of Deposition

While the deposit is being formed by electrophoretic migration and deposition on the anode, the reverse phenomenon of electroosmosis also takes place, in which the water migrates out of the deposited clay toward the cathode. The inner layer of the deposit thus becomes progressively more dry and its electrical resistance increases. In most of the later experiments, 10 minutes was selected as the standard time. An increase of the deposition time decreased the moisture content and slightly increased the consumption of energy, but there was no noticeable effect on the rate of deposition.

V. Temperature

Changes in temperature between 15° and 55°C. had no marked effect on the moisture content or on the rate of deposition. The decrease in viscosity associated with increasing temperature allowed the clay particles to migrate at the same velocity under a smaller potential gradient. Increasing temperature therefore favored a lower consumption of energy.

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Published by permission of the Director, Bureau of Mines, U. S. Department of the Interior.

[1] C. E. Curtis, "Electrical Dewatering of Clay Suspensions," *Jour. Amer. Ceram. Soc.*, **14** [3] 219–63 (1931).

[2] L. G. Hall, "Electrical Unwatering of Portland Cement Slurry," *Cement Mill and Quarry*, **33** [4] 28–34 (1928); *Ceram. Abs.*, **8** [6] 434 (1929).

[3] H. Wilson and H. G. Wilcox, "Electrical Dewatering of Portland Cement Slurry," "*Concrete-Cement Mill Section* (April, May, and June, 1932).

VI. Current Density

The moisture content decreased with an increase in current density, and the effect was more pronounced with more dilute suspensions. The rate of deposition was directly proportional to the current density up to 1.5 amp. per sq. dm. The weight of clay deposited per Faraday was thus a constant for a particular concentration of solids. The consumption of energy per unit of clay was also directly proportional to the current density. This is analogous to the lowering of resistance or I^2R losses when the current is lowered.

VII. Concentration of Solids in Suspension

The moisture content of the deposit decreased slightly as the concentration increased. The rate of deposition, and, therefore, the grams of clay deposited per Faraday, were roughly proportional to the concentration of solids. The consumption of energy per ton of deposit increased rapidly with decreasing concentration of solids; their relation seemed to be almost hyperbolic.

VIII. Hydrogen-Ion Concentration

The two electrolytes used in the main experiments were tetrasodium pyrophosphate and N-brand sodium silicate.

(1) Tetrasodium Pyrophosphate

The three derived functions had an inflection point at approximately pH 6.5. The consumption of energy was the least at this point, and the rate of deposition was the greatest. An increase in electrolyte concentration to pH 8.5 decreased the moisture content from 54 to 32%, but it adversely affected the rate of deposition and consumption of energy to a still greater extent.

(2) N-Brand Sodium Silicate

An increase in the concentration of electrolyte continuously decreased the consumption of energy and lowered the moisture content slightly. The rate of deposition increased 50% in the change from pH 4 to pH 9. No optimum point was reached with electrolyte additions up to pH 9.

The variation in consumption of energy observed with tetrasodium pyrophosphate was normal. Consumption of energy decreased to a minimum, after which the current carried by the added electrolyte apparently became more important. The effect of any particular soluble salt would have to be determined experimentally.

IX. Spacing of Electrodes

The moisture content of the deposit and the rate of deposition were unaffected by the spacing of the electrodes. The consumption of energy increased with the spacing of electrodes owing to the increase in ohmic resistance of the intervening suspension as the electrodes were separated.

X. Conclusions

As so many experimental variables are involved and three derived quantities must be considered, it is difficult to state definite optimum conditions for any one clay. The following conclusions summarize the effects of these variables:

(1) For minimum power consumption, the electrophoretic migration should be downward to utilize and not to oppose the gravity sedimentation; in any event, some nonelectrical method should be used to aid the movement of clay particles from the cathode to the anode.

(2) The time of deposition should be as long as possible without increasing the consumption of energy to an uneconomical figure.

(3) The temperature of the suspension should be as high as possible. Waste heat might be used to increase the temperature if the suspension flows so rapidly that the I^2R heat loss in the machine does not appreciably increase the temperature.

(4) The current density should be low to obtain low consumption of energy. The moisture content and the rate of deposition are benefited, however, by an increase in current density, and the optimum value therefore must be determined by the limitations in moisture content, the rate of deposition, and the consumption of energy per ton imposed on the process.

(5) The suspensions should be as concentrated as is consistent with the mechanical problems involved. Only a small part of the solids should be removed from the clay suspension each time it passes through the machine; the remainder should be recirculated and more clay added to it.

(6) For the particular ball clay studied, tetrasodium pyrophosphate gave slightly better deposition conditions than N-brand sodium silicate. The optimum consumption of energy and rate of deposition are confined, however, to a small pH range.

(7) The spacing of electrodes should be made as small as possible.

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NEW METHODS OF PURIFYING WATER FOR THE CERAMIC INDUSTRY*

By W. S. Morrison

Abstract

Inorganic and organic zeolites are discussed, and a description is given of the history of the development of the zeolite, including the theory of exchange absorption. The use of hydrogen and hydroxyl exchangers is emphasized as well as the preparation of these resinous materials. The application of the zeolite to the ceramic industry is also described.

I. Introduction

The soil chemists for a great number of years have known that various clays have exchange properties. The first soil chemist to discover this was Way[1] in England, who made known his discovery of the exchange reaction in certain Dover clay. Eichkorn discovered the reversible character of Way's reaction a few years later in Germany. For a generation thereafter, the possibilities of zeolite reaction lay dormant until Gans in Germany, at the beginning of the twentieth century, made use of the zeolite by the fusion of various silicates and aluminum salts.

The early synthetic zeolite was satisfactory for most purposes until the first World War, when it was discarded in favor of natural greensand because the greensand deposits of the east were faster in the regeneration cycle although they were lower in capacity per cubic foot.

Since 1918, a great deal of research has been conducted on synthetic zeolite, which is prepared by drying aluminosilicate gels. The resulting synthetic-gel zeolites have been popular during the past fifteen years. In 1932, the dehydration of synthetic zeolites by freezing was commercialized.

Burgess and McGeorge[2] cite four possible exchange reactions in soil as follows:

$$NaAl(OH)_4 + 3Na_4SiO_4 \longleftrightarrow Al\begin{matrix}SiO_4Na_3\\SiO_4Na_3\\SiO_4Na_3\end{matrix} + 4NaOH \quad (1)$$

$$2NaAl(OH)_4 + 3Na_4SiO_4 \longleftrightarrow Al\begin{matrix}SiO_4Na_3\\SiO_4Na_3\\SiO_4Al\end{matrix} + 8NaOH \quad (2)$$

$$3NaAl(OH)_4 + 3Na_4SiO_4 \longleftrightarrow Al\begin{matrix}SiO_4Na_3\\SiO_4Al\\SiO_4Al\end{matrix} + 12NaOH \quad (3)$$

$$4NaAl(OH)_4 + 3Na_4SiO_4 \longleftrightarrow Al\begin{matrix}SiO_4Al\\SiO_4Al\\SiO_4Al\end{matrix} + 16NaOH \quad (4)$$

Burgess and McGeorge tried these proportions, indicated in natural soil, keeping silicate constant at 3 mols and adding aluminum in 1, 2, 3, and 4 mols. The first precipitate was very slow; the second, more rapid; the third, quick; and the fourth, instant. All of them came out to the same end product in the presence of $CaCO_3$ and were analyzed at SiO_2 50.1, Al_2O_3 32.9, CaO 16.1, and Na_2O 0.2%.

Gans[3] later formed the following equation for the theory of base exchange:

$$\frac{\text{Ca in solution}}{\text{Ca in zeolite}} = K\left(\frac{\text{Mn in solution}}{\text{Mn in zeolite}}\right)\frac{1}{P}$$

$$\text{Log}_{10}\left(\frac{\text{Ca in solution}}{\text{Ca in zeolite}}\right) = \log 10\ K - \frac{1}{P}\log_{10}\left(\frac{\text{Mn in solution}}{\text{Mn in zeolite}}\right) \quad (5)$$

The sodium-zeolite process for treating water is well known, and applications have been found in many industries. The chief benefit of such water in the enamel industry is in the pickle room. With all of the calcium and magnesium solids exchanged for equivalent sodium ions, less alkali is required to break the water and the solution may be used for a longer period of time before dumping. With the water free of calcium and magnesium, scum in alkali tanks is also eliminated.

Heretofore a discussion of exchangers has been limited to those mineral exchangers of more or less natural origin, such as hydrated aluminum silicates. Because all of these natural or synthetic zeolites can be destroyed by the action of acids, even those in a dilute form, they can be labeled only as neutral exchangers. Although the natural greensands are more sturdy and less sensitive to acids than the synthetic zeolite, it is possible to replace exchangeable metal ions in greensand by hydrogen to a certain degree before the greensand is broken down. The inspiration to effect the decomposition of carbonates by means of hydrogen exchangers is apparently a recognition of this fact.

The proposal to do this work with inorganic exchangers failed because of insufficient information as to the durability of exchangers. The second group of soil constituents capable of cation exchange, however, comprises the humus compounds. The investigation of humus substances relating to their exchange properties came about principally in connection with the study of soil acidity and, in certain cases, by the action of neutral salts of strong mineral acids on the free humus acids present in the soil. The attempts of chemists to apply cation-exchange properties of humus substances, such as brown coal, to water purification were defeated

* Presented at the Forty-Third Annual Meeting, The American Ceramic Society, Baltimore, Md., April 1, 1941 (Whitewares and Materials and Equipment Divisions). Received April 2, 1941.

[1] T. J. Way, "Power of Soils to Absorb Manures," *Jour. Roy. Agr. Soc. Eng.*, **13,** 123 (1852).

[2] P. S. Burgess and W. T. McGeorge, "Zeolite Formation and Base-Exchange Reaction in Soil," *Ariz. Agr. Expt. Sta. Bull.*, No. 15 (1927).

[3] R. Gans, *Centr. Mineral., Geol.*, pp. 699–717, 728–41 (1913).

primarily because these materials proved to be exceptionally sensitive to alkalis.

To make cation-anion exchange material possible, therefore, a material sensitive to humification was needed. A number of products of carbonaceous nature, that is, wood, peat, lignite, anthracite, and mineral coal, accordingly were treated with concentrated acids, particularly sulfuric and phosphoric acids, to bring about humification, which is sometimes accompanied by partial oxidation and sulfonation.

These cation exchangers are durable in the presence of acids, such as sulfuric, and they may be applied as hydrogen exchangers. They resemble charcoal or certain active charcoals physically, and they are chemically active because of their hydroxyl groups which result from their pretreatment with sulfuric acid or oleum. The carbonaceous exchangers resemble graphite sulfonic acid in their physicochemical properties.

Various soils in nature have the properties that result in the exchange of negatively charged ions. There are many mineral constituents of arid soils, scapolites, and, in particular, the polyvalent hydroxides of aluminum and iron, that will exchange anions.

Such natural gels, as in the case of the cations, have not been introduced in practice because of their instability, particularly toward regenerating agents. Among the first studies of this nature, Kolthoff found that acids could be absorbed by using highly heated charcoal. It has therefore been necessary to develop a commercial material that is durable and has a high exchange power. The resinous exchangers, therefore, are used commercially and are related to the materials known as synthetic resins.

Most synthetic resins of course are chemically inert because no residual acid or base valences, which are a prerequisite for industrial material, are used in their preparation. Resinous exchangers, however, must be chemically reactive, and their fundamental characteristics, which are acid or base, remain after they are prepared. During manufacture, this activity in many cases is increased by the incorporation of groups especially active in exchange. The finished exchange material reacts reversibly with electrolytes.

Cation Exchange

$$\text{H-resin} + \text{NaOH} \longrightarrow \text{Na-resin} + \text{H}_2\text{O}$$
$$\text{Na}_2\text{-resin} + \text{CaSO}_4 \longrightarrow \text{Ca-resin} + \text{Na}_2\text{SO}_4$$
$$\text{Ca-resin} + 2\text{HCl} \longrightarrow \text{H}_2\text{-resin} + \text{CaCl}_2$$

In the anion resin exchanger, the anion material is a complex amine in which the alkyl groups are selected to give insoluble resins.

$$\text{R}\cdot\text{N} \begin{array}{|cc|} \hline \text{OH} & \text{H} \\ \text{OH} & \text{H} \\ \hline \end{array} \begin{array}{c} \text{Cl} \\ \text{Cl} \end{array}$$

$$\text{R}\cdot\text{N}\begin{array}{c}\text{Cl}\\ \\ \text{Cl}\end{array} + \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} \longrightarrow \text{R}\cdot\text{N}\begin{array}{c}\text{OH}\\ \\ \text{OH}\end{array} + 2\text{NaCl} + \text{CO}_2$$

The anion exchange formulas show this in more detail.

Anion exchange

$$\text{OH-resin} + \text{HCl} \longrightarrow \text{Cl-resin} + \text{H}_2\text{O}$$
$$\text{Cl}_2\text{-resin} + \text{Na}_2\text{SO}_4 \longrightarrow \text{SO}_4\text{-resin} + 2\text{NaCl}$$
$$\text{SO}_4\text{-resin} + 2\text{NaOH} \longrightarrow (\text{OH})_2\text{-resin} + \text{Na}_2\text{SO}_4$$

(1941)

The resinous material is presumed to be insoluble in the liquid medium in which the reaction occurs, and the material is of adequate stability, especially in aqueous or alcoholic solutions of acids, bases, and salts. It is possible, furthermore, to cause these reactions to go practically to completion in one direction by the use of a moderate excess of reagent.

The first resinous exchange materials to be proposed were from natural tannins. They were incapable, however, of meeting the high standard which industry requires of exchange material. From the study of these first tannins, it was therefore necessary (1) to increase the chemical and mechanical stability, raising the exchange capacity; (2) to develop high exchange velocity, improving the regenerability; and (3) to develop special types adapted to the particular process and condensation of these.

Poor starting materials, such as natural tannins, always contain certain amounts of foreign substances which form condensation products that have varying properties and unsatisfactory stability. Suitable primary materials for resinous exchangers are sometimes made from monovalent or polyvalent phenols and formaldehyde. Basic exchangers, fundamentally, are condensation products of aromatic amines with aldehydes, and they are also closely related to amine plastics. Strongly acidic or basic groups, such as alkyl sulfonic acids or alkyl polyamines or ammonium compounds, are incorporated into this type of resin. Such exchangers gave cation exchange over wide limits. A resin of the sample bakelite type carries sulfonic acid groups as the active elements. To prepare them, sulfonic acids or phenols are condensed with formaldehyde. The phenolic group may exert the direction of the entrance of the aldehyde group, perhaps into the para- or ortho-position. Para substitution is favored so much that when pure paraphenol sulfonic acid is condensed with formaldehyde the sulfonic groups are torn off and are replaced by oxymethyl groups. The resin formed contains only a fraction of the sulfonic groups of the original phenol and is a co-condensate of phenol and paraphenol sulfonic acid.

II. Use of Resinous Exchangers

The principal fields of application for the new resinous exchangers are (1) to soften water, (2) to reduce the salts in water that is heavy in carbonates, and (3) to remove salts from water by a successive exchange of hydroxyl and hydrogen ions. The third of these applications is particularly useful in the ceramic industry.

The complete removal of salts from water until recently was possible only by distillation. The use of resinous exchangers opens up a new approach to the removal of calcium magnesium salts from water. The process used is a double-filtration method.

The cations, in the first stage, are removed by the hydrogen exchanger. The partially treated effluent then is freed of anions in the second filter in which the acid radicals are absorbed for the hydroxyl ion. The apparatus consists of a pair of filter tanks, connections, and valves, and all of them must be resistant to acid and alkali to meet the requirements for regeneration.

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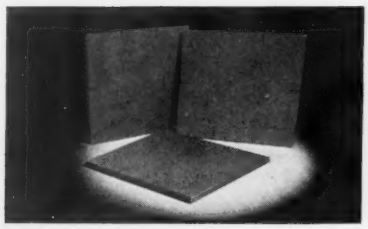

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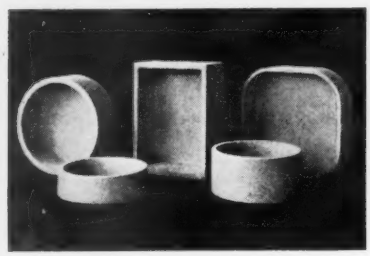
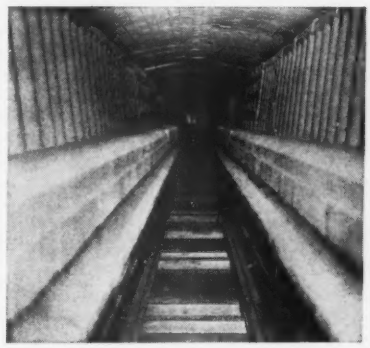


**Slim but Husky Saggers
Built for Long Life,
More Profitable Use of Kiln Space**

The old-fashioned sagger, built like a 10-ton truck or a professional strong man with bulging muscles — can stand the gaff at reasonable cost, *but how they eat up precious kiln space!* CRYSTOLON saggers are streamlined, built of super-strong and refractory silicon carbide, so that they use minimum space, yet stand up amazingly long against heat and abrasion and shock. Extra life, prevention of damage to your product in the kiln, soon covers their original cost. After that, CRYSTOLON saggers are practically putting money in your pocket every day.



**What Are the ALUNDUM Waves Saying?
"Unique Corrugation Means
Thinner Muffles, More Heat Transfer,
Lower Costs"**

Note the unique corrugated construction of the ALUNDUM muffle plates in this tunnel kiln. This corrugation means they can be thinner than flat plates, with no loss of strength. Of course this spells markedly greater heat transfer, greatly increased radiation surface and lower fuel costs.

When you buy or re-line a tunnel kiln, don't miss your chance to get maximum efficiency that will cut your fuel bills for the rest of the muffle's long life. Specify Norton's unique corrugated ALUNDUM muffle plates.

NORTON RESEARCH

Ingredient Number One in Longer Lived Refractory Products —

Refractory Shapes and Cements of CRYSTOLON (silicon carbide), ALUNDUM (fused alumina), and Fused Magnesia Grains

NORTON COMPANY, WORCESTER, MASS.

In the removal of acids and salts, the valence of the ions that are removed must be considered. The divalent sulfate ion is much more easily removed than the monovalent chloride ion. The acid strength of the anion is also a factor because the anion of a strong acid is removed more readily than that of a weak acid.

In this reaction, silica, which is a colloidal constituent of many waters, is not removed. There are, however, processes known for the removal of silica, and when they are coupled with anion-cation exchangers, they render water as free of solids as distilled water.

Most mill formulas in the enamel plant show that the frit is the largest addition that may safely be assumed to be pure. The next largest addition is water. Shands[4] states that (1) the addition of water may be troublesome if it varies in hardness or has high dissolved solid content; (2) the solid content of water often has a serious effect on the workability of enamel when it is used as a mill addition; and (3) a typical water, computed in terms of mill formulas, deposits 1/4 oz. of solids per 100 lb. of frit. These solids usually are compounds of sodium, calcium, or magnesium, such as carbonates, bicarbonates, sulfates, and chlorides, that act as powerful electrolytes on the milled enamel. Many of these materials impart only temporary set to the enamel and cause it to be erratic in set while it is being applied.

The problem of set in the ground coat becomes more troublesome when hard water is used for the milling because uniform dipping weight is difficult to hold when the consistency of the enamel is changing. When the dipping weight of the ground coat is held constant, the water content will change and will also give trouble.

The water that was used in the present work was pumped from a deep well. It showed a soap hardness that varied from 16 to 22 grains per gallon, depending on weather conditions. The hardness increased during dry weather. The enamel milled with this water came from the mill with a high set even though the usual setting-up agents were held low. It was necessary to age the ground coat almost exactly the same length of time each day or the water content would get out of line. Even with proper aging the set would sometimes break in the dip tank, which necessitated a further addition of calcium chloride, sodium nitrite, or some other electrolyte to restore the soluble salts to the ground coat that already contained too many soluble salts, making it still more erratic. There was also a marked tendency at times toward double draining.

To improve this condition, a trial run was made, using distilled water in the ground coat instead of well water. Such a marked improvement occurred that distilled water was used in all ground coat for more than six months. A variation in the time of aging the ground coat could be as much as forty-eight hours without causing too much variation in the water content when it was brought to dipping weight. A slightly greater amount of the setting-up agent was required in the mill formula, but the resulting set was more permanent and subject to fewer variations with changes in temperature or variations in suspending qualities of clay which may affect the consistency of the enamel.

Because its high cost was the only objection to the use of distilled water, a trial run was made on a synthetic distilled water, that is, a water in which the solids have been removed chemically rather than by distillation. The cost of one hundred gallons of this water was found to be about the same as one gallon of distilled water. No difference between the action of the distilled water and synthetic distilled water on the ground coat has yet been detected.

A cover-coat test run was made using synthetic distilled water. The change at first was not as marked as in the case of ground coat, although the set of the enamels coming from the mills was not so high as it had been when well water was used. After several runs, however, the consistency of the cover-coat enamels was improved and more uniform spray weights could be held. In addition to the set difficulties of the cover-coat enamel, a tendency to scumming occurred during hot weather, especially when relative humidity was high. This led to the theory that too much moisture existed in the area of the furnace. This scumming condition, however, did not reappear after the synthetic distilled water was substituted for well water.

Fellows* determined that when water with a low hardness value was used with a slip ground to 35 gm. of pick-up per sq. ft., the loss of set was reduced to 33.8 gm. in an 8-hr. period. Tests were run on the loss of set, and at the end of ten days the pick-up was 22 gm. per sq. ft. When solid free water was used, the loss of set at the end of ten days was not so great as that during the first day with hard water; the pick-up was 33 gm. per sq. ft. at the end of the tenth day.

The use of exchangers of the type described has removed one variable from enameling problems. The use of solid free water also controls the exchange of the colloidal clays used in enameling slip. The addition of controlled amounts of buffer solution will govern some of the characteristics of the finished slip.

Although the discovery of base exchangers, particularly of hydrogen and hydroxyl exchangers, has brought out many ideas for their application, a considerable number of suggestions still await technical solution.

ILLINOIS WATER TREATMENT COMPANY
ROCKFORD, ILLINOIS

Discussion†

E. A. Hauser

You stated that the exchange of SO_4 is easier than the exchange of Cl. How do you account for this?

W. S. Morrison

It is a characteristic of the material for which I cannot account; more work probably will be done on this problem.

E. A. Hauser

Do you mean that a sulfate attached to a resin can be exchanged more readily than a chloride? For example, if R represents a radical and N is the nitrogen, you obtain H_2O

[4] E. H. Shands, "Treated Water in the Enamel Industry," *Proc. Porcelain Enamel Inst. Forum, Fifth Forum*, pp. 40–45 (October, 1940); *Ceram. Abs.*, **20** [4] 86 (1941).

* R. L. Fellows, Chicago Vitreous Enamel Product Co., Cicero, Ill.

† This Discussion followed the presentation of Mr. Morrison's paper.

and Cl_2-resin. The radical, in water, will be the cation and the chlorine will represent the anionic setup. Then do you exchange the Cl for the OH groups?

W. S. Morrison

That is right.

E. A. Hauser

Can SO_4 groups be exchanged more readily than the chlorine groups?

W. S. Morrison

The chlorine seems to exchange more readily; in other words, with this reaction there is possibly more slippage on a water that contains 20 parts of chloride in one million parts of water; we are likely to have a one-half part per million slippage of the chloride radical, but such a slippage would not occur until at least 40 grains of sulfate are added.

F. P. Hall

How do the base-exchange capacities of these resins compare with those of inorganic materials?

W. S. Morrison

All of these exchange reactions are comparatively high—much more than you would suspect. In the calcium-carbonate equivalent, the exchange would be roughly 6000 grains per cu. ft. on the cationic material and possibly 10,000 grains on the anionic material, which is very high.

With steam-still requirements in a mill room that need a volume of 150 gallons of steam-distilled water per hour, the still is large and is costly to operate. The floor rates of 12 gallons per sq. ft. per minute on the cationic material determines the volume needed per minute. A cubic foot of cationic or anionic material could give one thousand gallons of total water on a comparatively hard water at possibly 400 to 500 gallons per hour. This rate is much higher than could possibly be obtained from a steam still.

C. W. Parmelee

How much does it cost per thousand gallons, all costs considered, to produce this solid-free water? Has this ever been used for decalcomania application to avoid water-spotting?

W. S. Morrison

This process is in constant use to prevent water-spotting in decalcomania. To figure the cost per thousand gallons on a typical hard water, that is, water of between 20 and 30 grains of hardness, 10 lb. of sulfuric acid (commercial grade), and 0.16 lb. of sodium carbonate would be needed.

VACUUM LATHE FOR TURNING FINE CLAYWARE*

By F. H. Norton

The production of thin porcelain by hand-throwing and subsequent turning on the potter's wheel requires a great deal of skill and experience, and students are often discouraged by the lack of results. It is impracticable, furthermore, to provide a wooden chuck for off-hand pieces. To simplify this process, a machine that gives good results has been developed recently in the Ceramic Laboratory of the Massachusetts Institute of Technology.

The machine consists essentially of a light lathe head having a faceplate with a vacuum connection in the center so that the leather-hard piece can be set against the plate, the vacuum can be applied, and the turning operation can be carried out in perfect confidence that the piece will stay in place. The adhesion, in fact, is so strong with the average piece that it cannot be removed from the faceplate without disconnecting the vacuum.

This machine can be made out of standard parts purchased at any hardware store with a little additional machining. The total cost of the machine now in use was $15.00, including the motor and aspirator for the vacuum.

The lathe is made from a standard polishing head or headstock (1) (see Fig. 1). The shaft (2), about $^3/_8$ in. in diameter, is drilled through the center with a $^1/_8$-in. hole. One end is reamed out to $^3/_{16}$ in. in diameter and 1 in. deep to take the vacuum connection (3), which should be lapped into good contact with the end of the shaft; this part must be kept well oiled. The spring (4) holds the connection against the shaft and keeps it from turning. A rubber vacuum tube can be slipped over part (3).

A hub (5) on which the true running disk (6) is soldered is clamped on the other end of the shaft. This disk should be of brass of any desired diameter with fine concentric grooves in the face to aid in centering. It is driven by the pulley (7) and V-belt (8) from a small countershaft, which in turn is connected to a $^1/_4$-h.p. motor by another belt and a four-step cone pulley to vary the speed from about 300 to 1800 r.p.m.

The adjustable tool rest (9), similar to that used on wood-turning lathes, steadies the tool for turning the piece (10).

When this equipment is used, the rim of the leather-hard piece is rubbed on a piece of wet glass or marble to produce a smooth surface completely around the rim. The piece is then put on the faceplate and centered by the nearest

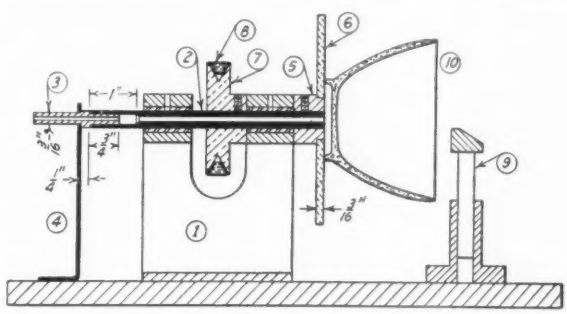


Fig. 1.—Cross section of vacuum lathe for turning cups and bowls.

* Received May 3, 1941.

concentric marking ring, the vacuum is applied, and the lathe is started up at the speed appropriate for the size of the piece. The bottom of the piece and, if desired, the outside surface can be readily finished. The vacuum is broken and the piece is removed from the wheel and is applied the other way around, care being taken to center it accurately (see Fig. 1). The inside and outside can be turned in this position. If the piece is left on the wheel for a long time, it may be necessary to add a little water at the contact point with a soft brush so that the vacuum will be maintained. It is well to finish eggshell pieces completely on the inside and then to complete the operation on the outside because the combination of the outward tool pressure and of the centrifugal force may cause breakage.

An adjustable tool rest which can be clamped firmly into position is essential. The tools used are readily formed from discarded power hacksaw blades which may be obtained from any machine shop. The blades are ground on the ends to the desired shapes, and frequent sharpening may be necessary even when the blades are made of hard steel.

The vacuum is obtained by an aspirator (such as is used in the chemical laboratory for filtering) which is attached to any water faucet; many laboratories, however, are supplied with vacuum lines.

Division of Ceramics
Department of Metallurgy
Massachusetts Institute of Technology
Cambridge, Massachusetts

CERAMIC HISTORY

ARTHUR LOUIS DAY*

By E. C. Sullivan

Arthur Louis Day was born on October 30, 1869, and was reared in the little New England village of Brookfield, Massachusetts. He headed toward college only through the accident that an energetic young high-school teacher offered to him and to a classmate two years of private instruction in preparatory courses. Self-possessed as he seems today, he entered Yale as a boy so diffident and so unfamiliar with the ways of people that it was not until his junior year that he learned how to take a part in the commonplace activities of student life. In his studies, however, he was under no disadvantage, and at graduation he was awarded outstanding distinction through the appointment as Sloane Fellow in Physics, an appointment which he held for two postgraduate years.

Shortly after graduation he took charge of Edward S. Dana's classes in physics when that eminent professor retired because of illness. The clarity of exposition which is a noteworthy trait of later years must have been in evidence, for the scanty laboratory facilities of those days were soon overwhelmed by students flocking in unheard-of numbers into the advanced physics courses, and two years later Dr. Day found himself with William Lyon Phelps the choice of the senior classes as the most popular instructor in college. His work for the Ph.D. degree completed, he felt the need of wider experience, and after five years of service he resigned his instructorship.

Friedrich Kohlrausch was then at the height of his activity and toward him Dr. Day directed his footsteps, only to learn on arriving in Germany that Dr. Kohlrausch had given up university teaching to preside over the Reichsanstalt at Charlottenburg. So it happened that instead of following the usual course and matriculating at a university, Dr. Day entered the Reichsanstalt as a volunteer assistant, and in a few months he became a member of the paid scientific staff, probably the first instance of a non-German attaining such recognition. Obstacles naturally presented themselves to a foreigner seeking to establish himself on a footing with the native born, but Dr. Day achieved the feat, difficult for Americans, of consorting with the people of the land in which he was living, and he thus acquired full mastery of the foreign tongue and came into intimate relationship with his associates and with other celebrities of the German scientific world. A stimulating feature of this period was the contact with such outstanding physicists as Abbé, Drude, Planck, Nernst, Warburg, W. Wien, and others, who, constituting a Board of Inspection, made regular visits to Charlottenburg, in the course of which the entire staff participated in the discussion of research problems.

Dr. Day's own work at the Reichsanstalt with Dr. Holborn resulted in a series of classical papers which extended the gas thermometer temperature scale to the gold point with practically present-day precision. In later years at the Geophysical Laboratory, in Washington, D. C.,[1] he carried it to its present limit at the palladium melting point.

American geologists, among them Walcott, Gilbert, Becker, and a few others, had given some thought to the application of high-temperature chemistry and physics to the elucidation of geological problems at the United States Geological Survey in Washington, and Carl Barus on a visit to Charlottenburg recognized in Dr. Day a man of ideal training for the purpose. The opportunity appealed to Dr. Day, and he was invited to report in Washington. When, however, he was informed that he could receive only a temporary appointment while preparing for the examination which he must pass for permanent tenure, he replied characteristically that he had crossed the ocean not on his own initiative but on that of the department, that he wanted no temporary appointment, and that he would take no examination then or thereafter. There

* Reprinted from *Ind. Eng. Chem., News Ed.*, **14** [17] 347 (1936).

[1] For story of Geophysical Laboratory, see *Bull. Amer. Ceram. Soc.*, **13** [1] 17 (1934).

ensued a pause in the interview until C. D. Walcott, wise director of the Geological Survey, reconciled the divergence of views by remarking that he could give no guaranties but that actually certain temporary appointments had proved to be among the most permanent in the service. On that basis then, in 1900, Dr. Day was installed on the top floor of the old Geological Survey building in Washington as physical geologist. Soon thereafter the paper by A. L. Day and E. T. Allen on feldspars appeared, which ushered in a new era in the scientific study of mineral formation. The year 1907 marked the founding of the Geophysical Laboratory of Carnegie Institution, which Dr. Day has directed from its inception.

It was in the early years at Washington that Dr. Day became interested in glass manufacture, his familiarity with high-temperature work having led to consultation by the Corning Glass Works in what probably was the first serious attempt to control commercial glassmelting by routine temperature measurement. Corning had always shown enterprise in the development of glasses and of manufacturing methods, and following these consultations a long-cherished project culminated when systematic glass research was undertaken at Corning on a comprehensive scale. Dr. Day eventually became vice-president of the Company in charge of manufacturing and research activities, and for a short period, on leave of absence from the Geophysical Laboratory directorship, he devoted his entire time to glass manufacture. In the end, the attraction of geophysical research outweighed that of glass manufacture and he returned to Washington, retaining his position as an officer and consultant of the Corning Glass Works.

Early in the World War a vigorous champion of the Germany in which he had spent happy years and to which he was bound by intimate personal ties, he saw but one course when his own country became involved, and he plunged into a vital war industry—the manufacture of optical glass for field glasses, periscopes, and range finders. What had been a secret art Dr. Day promptly established on a scientific basis, and about 97% of all optical glass used by the American forces during the war was made under his direction. Later, in the development of the huge telescope for the California Institute of Technology, he was from the first a steadfast advocate of a low-expansion molded glass for the reflecting mirror.

As director of the Geophysical Laboratory, Dr. Day has brought to bear on the exceptionally difficult problems of the interior of the earth, "the dark continent of science," unusual ability to see over the whole field and focus on it light from such diverse sources as chemistry, physics, geology, volcanology, the study of hot springs and fumaroles, and seismology. In the laboratory and in the field he has pushed forward the frontiers of knowledge of high-temperature thermometry and of the processes of rock formation. Equilibrium conditions have been worked out for silicates melting at white heat, as well as for minerals forming from water solution at lower temperatures. Annual visits to Yellowstone Park over a period of years furnished material for the monumental volume by E. T. Allen and A. L. Day on the Hot Springs of Yellowstone Park. For the sake of first-hand observation on volcanic action, Dr. Day has braved, at personal risk, fumes and fire of the interior of a Hawaiian crater. He has been active as chairman of the Advisory Committee on Seismology of the Carnegie Institution of Washington, which in 1921 founded the Seismological Laboratory in Pasadena for the study of local earthquakes, and he has since been in charge of its operations.

Honors and responsibilities have come in recognition both of scientific achievement and of administrative record. Honorary doctorates from American and foreign universities, the John Scott medal of the A.I.M.M.E., home secretaryship and now vice-presidency of the National Academy of Sciences, election as foreign associate of European academies and scientific societies, honorary membership in The American Ceramic Society and the Society of Glass Technology (British), bank directorships, the vice-presidency of Corning Glass Works and appointment to the Commission of Inquiry on Public Service Personnel (1934) are some phases of such recognition, and others have been turned aside which would have trespassed too greatly on research problems.

Although reserved in manner and precise in speech, tenacious of his opinions, and a doughty opponent in discussion, Dr. Day is, as one friend writes, "among his intimate friends one of the most genial and gay human beings I have ever known, with a fine discrimination of good food and good wine and good living generally." His vast range of information, excellent memory, and unusual command of the English language contribute to the making of a most entertaining companion. Cultivation of dahlias in the early morning hours on his country place at Bethesda, Maryland, in the suburbs of Washington, and now and then an evening following the lure of the four matadors of skat are among his recreations.

University instructor, scientific investigator of the first rank, administrator, manufacturer, bank director—a varied and distinguished career, to which a new chapter may well be added when, on retirement from routine responsibilities this year (1936), he is in a position to embark on fresh adventures.

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AUTUMN MEETING SCHEDULES

Art: Blue Ridge, N. C., August 1–2 (for program see p. 257, this issue)

Enamel: Porcelain Enamel Institute Forum, Ohio State University, October 8–10

Glass: Conneaut Lake, Pa., September 12–13

Materials and Equipment and White Wares: Summit Hotel, Uniontown, Pa., September 19–20

Refractories: Granville Inn, Granville, Ohio, September 5–6

Structural Clay Products with Structural Clay Products Institute: Mayflower Hotel, Washington, D. C., November 4–6

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INSTITUTE OF CERAMIC ENGINEERS SEEKS OCCUPATIONAL DEFERMENT FOR CERAMIC ENGINEERS

The following letter was sent on May 26, 1941, to the Committee on Higher Education in National Defense, American Council on Education, Washington, D. C.

In behalf of the Institute of Ceramic Engineers of which I am President and which consists of more than three hundred graduate ceramic engineers, I would like to call your attention to the need of occupational deferment from military service for undergraduate and graduate students in ceramic engineering courses. I am approaching your Committee in this connection because Bulletin No. 11, which you issued on April 24, indicates that you have already been successful in securing recognition by the War Department of the importance of occupational deferment for students in other engineering courses, such as civil, electrical, chemical, mining, and mechanical engineering. It is my purpose, therefore, in writing to you, to enlist your support in obtaining similar action in regard to ceramic engineering students.

Ceramic engineering prepares men for work in various industries, many of which are extremely important to the National Defense program, for example, the manufacture of (1) refractory products for the steel industry and many of the nonferrous industries, (2) abrasives for the mechanical industries, (3) porcelain insulators for power lines, radio, and all types of electrical equipment, (4) glass products of all kinds, (5) sanitary porcelain products such as toilets and bathtubs, (6) structural clay products used in the building industries such as brick and tile, and (7) cement. From this it is apparent that ceramic engineers are important to a wide variety of industries and that they are directly or indirectly taking part in many phases of the National Defense program. Training in ceramic engineering has much in common with that in chemical and metallurgical engineering, but the emphasis is principally on the nonmetallic products already listed which are made by high-temperature treatment and which require technical specialists at every stage in the process.

The supply of graduate ceramic engineers under present national conditions is not too plentiful and a shortage has already developed. Many of this year's graduates will not become available to the industry because of their membership in the R.O.T.C., which will require immediate military service. Our organization, therefore, is convinced that it is necessary that the training of ceramic engineers in the schools is not interrupted and that they, therefore, are given consideration by the local draft boards for occupational deferment.

We note in your Bulletin No. 11 the statement by Brigadier-General Hershey that the Bureau of Labor Statistics is at present studying other professional occupations besides the engineering occupations, which I have already mentioned, to determine whether a shortage exists and whether they should be considered for occupational deferment. We hope that it will be possible for you to exert your influence to have ceramic engineering also included in this study by the Bureau so that our ultimate objective may be realized.

We know from past experience that unless action of this kind is taken many of the present ceramic engineering students who will be called to military service before the completion of their academic work will be permanently lost to the profession. On the other hand, if these men are allowed to complete their work, even though they should be called at that time into military service, they would in most cases again return to the profession. We feel, therefore, that the action which we are recommending is of vital importance in maintaining an adequate supply of ceramic engineers.

I know that every member of our organization will appreciate any assistance your Committee can give us, and if you have any suggestions as to any further action that we should take on this matter, I shall be glad to hear from you.

—E. H. FRITZ, *President*

ART DIVISION AUTUMN MEETING
AUGUST 1 AND 2, 1941 BLUE RIDGE, N. C.

The autumn meeting of the Art Division will be held at Blue Ridge, N. C., on Friday and Saturday, August 1 and 2, 1941.

The following program has been planned.

Friday, August 1, 9:00 A.M.

"Market Value of Good Design in Studio Ceramics" by GENEVIEVE LAWLER, Associate Arts Studio, Swannanoa, N. C. Miss Lawler will exhibit examples of pottery made by the potters of the Southern Highlands.

"A Résumé of the Ceramic Projects from the NYA in Georgia" by JACK SMOOT, Director of Ceramics, NYA for Georgia, Atlanta, Ga. Mr. Smoot will illustrate his lecture with several objects made by the NYA in Georgia under his supervision.

Friday, August 1, 8:00 P.M.

"Pottery Making Among the Catawba and Cherokee Indians," an illustrated lecture in Lee Hall by VLADIMIR FEWKES, University Museum, Philadelphia, Pa.

Saturday, August 2, 9:00 A.M.

"Approach to Ceramic Sculpture" by EUGENE DEUTSCH, Chicago, Ill. Mr. Deutsch will demonstrate processes and will exhibit a collection of contemporary ceramic sculpture.

"Ceramic Equipment and Materials" by CAREY HANSARD, Atlanta, Ga.

Friday afternoon will be given over to visits to neighboring potteries and to demonstrations and participation in the pottery workshop. An invitation has been extended to the group to visit the Southern Potteries plant at Erwin, Tenn.

—KENNETH E. SMITH, *Chairman, Art Division*

Knowledge Is Acquired by Communication

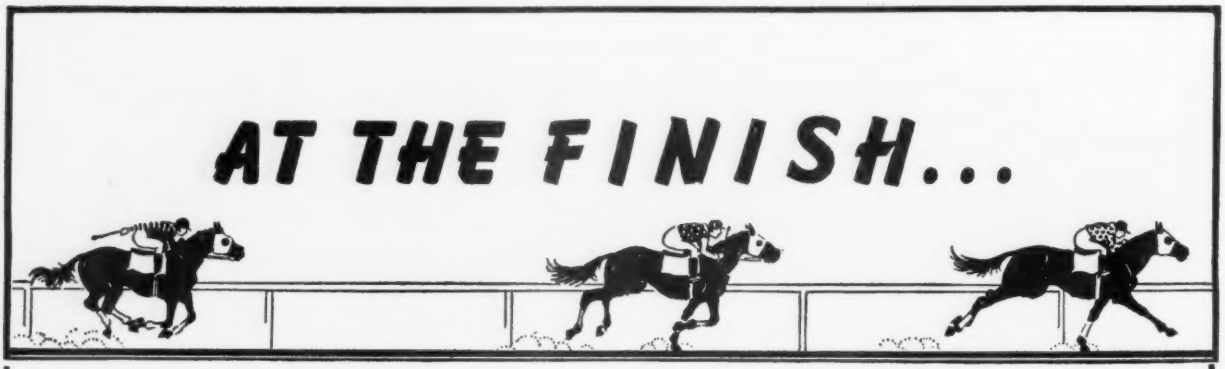
PAID MEMBERS ON GOOD SHIP CERAMICS

Each year in the July issue of *The Bulletin* the curve showing the ever-rising tide of new members has been published. The tide continues to rise; there has been a net gain of 53 paid members for the period of June 30, 1940, to June 30, 1941.

In the calendar year of 1940 there was a net gain of 173 in the number of paid members, but the war overseas and the service drafting at home have caused a considerable number of withdrawals of paid members. In spite of the 173 net gain in 1940, the count on June 30, 1941, shows a net gain of only 53 paid members over the count made on June 30, 1940.

The number of new members on the "Good Ship Ceramics" is increasing but not commensurate with the increased operating costs or with the increased urgency for cooperative pooling of research observations.

The total of paid members on June 30, 1941, is 2171.



January 1 **2280**

June 21 **2169**

December **?**

Here is the Membership record for the year 1941 to date. The FINISH depends on you.

If you invite a friend—interested enough in ceramics to advance his education and contacts—to join The Society the questioned finish will be easy to predict. Please write The American Ceramic Society, 2525 North High St., Columbus, Ohio, for application cards or send in the names of the corporations and individuals wishing to join, and an application card will be sent immediately.

Paid Membership Record

Date of Record	Members Paid		Deferred	Subscriptions	Monthly Sales	Total Circulation
	Personal	Corporation				
December 20, 1940	1995	260	25	574	220	3074
January 20, 1941	2007	262	27	594	220	3110
March 10, 1941	2023	257	26	620	220	3146
April 21, 1941	1794	247	47	563	220	2871
May 21, 1941	1839	249	47	580	220	2935
June 21, 1941	1875	249	45	584	220	2973

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Seagram, Joseph E., & Sons, Inc., Louisville, Ky.
Shenango Pottery Company, New Castle, Pa.
Simonds Worden White Co., Dayton, Ohio
Smith & Stone, Ltd., Georgetown, Ontario, Canada
Solvay Process Company, Syracuse, N. Y.
Spinks, H. C., Clay Co., Newport, Ky.
Square D Company, Detroit, Mich.
Standard Brick and Tile Corp., Evansville, Ind.
Standard Lime & Stone Co., Baltimore, Md.
Standard Sanitary Mfg. Co., Louisville, Ky.
Star Porcelain Co., Trenton, N. J.
Stark Brick Co., Canton, Ohio
Stauffer Chemical Co., Inc., New York, N. Y.
Steele, J. C., & Sons, Statesville, N. C.
Sterling Grinding Wheel Co., Tiffin, Ohio
Structural Clay Products Institute, Washington, D. C.
Stupakoff Laboratories, Inc., Latrobe, Pa.
Summitville Face Brick Co., Summitville, Ohio
Sur Enamel & Stamping Works, Ltd., Calcutta, India
Surface Combustion Corp., Toledo, Ohio
Swindell Brothers, Baltimore, Md.
Swindell-Dressler Corp., Pittsburgh, Pa.

Taylor, Smith, & Taylor Co., Chester, W. Va.
Texas Mining & Smelting Co., Laredo, Texas
Titanium Alloy Mfg. Co., Niagara Falls, N. Y.
Toyo Toki Kaisha, Kokura City, Japan
Trenton Potteries Co., Trenton, N. J.
Twyfords, Limited, Stoke-on-Trent, England
Tyler, W. S., Company, Cleveland, Ohio

Union Electrical Porcelain Works, Inc., Trenton, N. J.
United Clay Mines Corp., Trenton, N. J.
United Glass Bottle Mfrs., Ltd., London, England
United States Gypsum Co., Chicago, Ill.
Universal Clay Products Co., Sandusky, Ohio
Universal Dental Co., Philadelphia, Pa.
Universal Sanitary Mfg. Co., New Castle, Pa.

Vanderbilt, R. T., Company, New York, N. Y.
Vereeniging Brick & Tile Co., Ltd., Vereeniging, Transvaal, South Africa
Vesuvius Crucible Co., Swissvale, Pa.
Victor Insulators, Inc., Victor, N. Y.
Vitrefrax Corporation, Los Angeles, Calif.
Vitreous Steel Products Co., Cleveland, Ohio
Vitro Manufacturing Co., Pittsburgh, Pa.

Wallace China Co., Ltd., Huntington Park, Calif.
Waltham Grinding Wheel Co., Waltham, Mass.
Washington Porcelain Co., Washington, N. J.
Wayne Laboratories, Waynesboro, Pa.
Western Brick Co., Danville, Ill.
Western Electric Co., Chicago, Ill.
Westinghouse Electric & Mfg. Co., Derry, Pa.
West Virginia Brick Co., Charleston, W. Va.
Wheeling Steel Corp., Yorkville, Ohio
Wisconsin Porcelain Co., Sun Prairie, Wis.

CORPORATION MEMBERSHIPS ARE PROFITABLE INVESTMENTS

NEW MEMBERS FOR JUNE

Personal

*CREW, HORACE F., 866 E. Broad St., Columbus, Ohio.
DALTON, ROBERT H., 152 Watauga Ave., Corning, N. Y.; chemist, Corning Glass Works.
KUMAR, RAJ, Khemchand Raj Kumar Crucible Works, Jullundur City, India; general manager.
*LOWE, JOHN L., Battelle Memorial Institute, 505 King Ave., Columbus, Ohio.
MCNAUGHTON, RONALD R., c/o Central Technical Library, Consolidated Mining & Smelting Co. of Canada, Ltd., Trail, British Columbia, Canada; chief metallurgist.
SCRIBNER, ROGER G., 39 Washington Ave., Tiffin, Ohio; chief ceramic engineer, Sterling Grinding Wheel Co.
SIMONS, T. MITCHELL, JR., Habersham Resident Project, NYA for Georgia, Clarkesville, Ga.; ceramic supervisor.

*Former member of The Society rejoining.

Student

University of Illinois: ROBERT R. ROUGH.
Iowa State College: LLOYD L. WELLS, JR.
North Carolina State College: SAMUEL L. THOMAS, JR., and HENRY H. THOMAS.

MEMBERSHIP WORKERS' RECORD

Personal

J. T. Littleton	1	Office	6

Student

C. M. Dodd	1	W. W. Kriegel	2
R. K. Hursh	1		
		Grand Total	**11**

ROSTER CHANGES DURING JUNE*

BREMOND, PIERRE, Cie Générale de Construction de Fours, 80 Rue Gorge de Loup, Lyon, Vayse, Rhône, France (Sèvres, France)
BRISCOE, JOHN W., Westfield, Ill. (Indianapolis, Ind.)
BUCHHOLZ, RUSSELL A., Vitro Manufacturing Co., Corliss Sta., Pittsburgh, Pa. (Kenmore, N. Y.)
COOK, HERMAN L., 220 Collingwood Ave., Dayton, Ohio (Pittsburgh, Pa.)
CROCKETT, WILLIAM E., 305 Gardner Ave., Trenton, N. J. (Rolla, Mo.)
DAMMANN, ARTHUR, 37–51 79th St., Jackson Heights, N. Y. (Amityville, N. Y.)
GALINDO, GABRIEL, Panama, Republic of Panama, Central America (Atlanta, Ga.)
GENTSCH, B. F., Company I, 53rd Quartermaster's Regiment, Fort Bragg, N. C. (Trenton, N. J.)
HAZEL, JOHN J., 2108 S. Main St., Findlay, Ohio (Cleveland, Ohio)
HENDRICKSON, V. E., 5567 Hampton St., Pittsburgh, Pa. (Aspinwall, Pa.)
JONES, HARLOW G., 654 E. Main St., Owosso, Mich. (Beaver, Pa.)
KING, BURNHAM W., JR., Harshaw Chemical Co., 1945 East 97th St., Cleveland, Ohio (Urbana, Ill.)
KOLSTAD, JOHN A., Ely Court and High St., Metuchen, N. J. (Perth Amboy, N. J.)
LESTER, FRANK P., The President, Reading Rd. at Greenwood Ave., Cincinnati, Ohio (New York, N. Y.)
ROLKE, HERBERT J., c/o "Cimex" Ltda., Rua Mexico 168, 11 and Sala 1105, Rio de Janeiro, Brazil (São Paulo, Brazil)
SCHLIENTZ, DONALD T., 1509 2nd Ave., Bessemer, Ala. (Falmouth, Mass.)
SHONFELD, T. H., 2222 Coventry Rd., Cleveland Heights, Ohio (Washington, D. C.)
SOMMERVILLE, JAMES L., Company A, 28th Battalion, Engineer Replacement Center, Ft. Leonard Wood, Mo. (Bridgeton, N. J.)
TRABERT, LOREN A., Route 2, c/o Corbin's, Antioch, Ill. (Macomb, Ill.)
TURNBULL, GALE, 2634 Portland St., Los Angeles, Calif. (Vernon, Calif.)
ZWERMANN, CARL H., Box 162, Robinson, Ill. (Seattle, Wash.)

* Address in parentheses is former address.

PERSONAL NOTES

G. E. F. LUNDELL ELECTED A.S.T.M. PRESIDENT

G. E. F. Lundell, chief chemist of the Division of Chemistry, National Bureau of Standards, Washington, D. C., has been elected president of the American Society for Testing Materials.

Dr. Lundell has been a member of The American Ceramic Society since 1926 and is also a Fellow of The Society.

LAWRENCE EUGENE BARRINGER HONORED AT NEW YORK STATE COLLEGE OF CERAMICS

Honorary Degree of Doctor of Science

The honorary degree of Doctor of Science was conferred upon Lawrence E. Barringer, General Electric Co., Schenectady, N. Y., at the commencement exercises of the New York State College of Ceramics in June. Dr. Barringer is Trustee of the Art Division of The Society.

Others Receive Degrees

George Blumenthal received the professional degree of ceramic engineer, and George H. Mann, a senior engineer, was awarded the prize and certificate of award of the Ceramic Association of New York for submitting the best senior thesis.

There were thirty-seven ceramic engineers, eighteen glass technologists, and eleven industrial ceramic designers in the 1941 graduating class. Almost all of the graduates secured employment before graduation.

NECROLOGY

WILLIAM BURTON

Word has been received of the death of William Burton, managing director of the Pilkington's Tile & Pottery Co., Ltd., Clifton Junction, near Manchester, England. He was seventy-nine years old. Mr. Burton had many personal acquaintances and friends in the United States and was widely known because of his writings and activities in ceramics.

SABURO MOMOKI

Saburo Momoki, president of the Toyo Toki Kaisha, Ltd., Kokura, Japan, died recently in Japan. Mr. Momoki had been a Personal Member of The American Ceramic Society since 1920 and had been a Corporation Voter since 1923. He was affiliated with the White Wares Division.

Forty-Fourth Annual Meeting
Cincinnati, Ohio
April 19–25, 1942

SCHOOL NOTES

UNIVERSITY OF WASHINGTON

Carl H. Zwermann, acting head of the Department of Ceramics, University of Washington, Seattle, Wash., began a year of active duty in the Engineers Reserve of the Army on July 1. He has been given a year's leave of absence, and his place will be taken by Joseph A. Pask.

Joseph A. Pask

Mr. Pask received his Bachelor of Science degree at the University of Illinois in 1934 and his Master's degree at the University of Washington in 1935. He then worked for a year at the Willamina Clay Products Co., Willamina, Oreg. In the fall of 1936, he returned to the University of Illinois to obtain his Ph.D. degree. He held an Engineering Experiment Station fellowship until the spring of 1938, at which time he became an instructor, the position which he still holds and from which he has a year's leave of absence. He is completing work on his Ph.D. degree and will be employed this summer at Norris, Tenn.

UNIVERSITY OF ILLINOIS

News of Graduate Students

H. A. Van Derck Fréchette, who has held a graduate school scholarship in ceramic engineering during the past year at the University of Illinois, has received an appointment as teaching assistant at the New York State College of Ceramics, Alfred, N. Y., for 1941–1942. He received his Master of Science degree from the University of Illinois in June, 1940, after spending two years as a research graduate assistant in the Engineering Experiment Station.

A. R. Rodriguez, Manila, Philippine Islands, received his Ph.D. degree in ceramics from the University of Illinois this year. After spending several months visiting manufacturing plants in this country, he will go back to Manila in September to start a Department of Ceramics at the University of the Philippines.

He received his B.S. in 1931 and M.S. in 1938 from the University of the Philippines. After graduation, he served as an instructor of physical chemistry at the same University before coming to the United States to study ceramics.

WEST VIRGINIA CERAMIC EXTENSION COURSES AT NEWELL, W. VA.

Ceramic Art Exhibit

The fourth annual exhibition of the work of the students of the University of West Virginia Extension Courses in ceramic art opened in the East Liverpool, Ohio, Public Library on June 26. Diplomas and prizes were awarded at that time.

Pottery manufacturers, organizations, and business men contributed generously to give encouragement to the successful students (contributions varied from ten to one hundred dollars). An independent jury judged the work and awarded the prizes. The classification of prizes and amounts, however, was decided by the faculty committee.

Thermochemical Mineralogy

The subjects studied in the science classes were difficult, as may be shown by the following final examination given to students in thermochemical mineralogy.

Answer all three questions.

In the equilibrium diagram of the system Al_2O_3–CaO–SiO

1. Trace the progress of melting of the composition CaO 10, Al_2O_3 40, and SiO_2 50%. If 100 lb. of batch are used, calculate by the various lengths of the levers (*a*) how much melt there is, how much undissolved crystal phase is present, and what the composition of the crystal phase is when all of the SiO_2 has gone into solution and (*b*) how much undissolved crystal remains when all of the SiO_2 and anorthite have gone into solution.
2. Trace the progress of crystallization of a melt of the composition CaO 33.5, Al_2O_3 30.0, and SiO_2 36.5%. If 100 lb. of melt are used, calculate by the various lengths of the levers the amount of crystal phase separated out and the composition of the crystals when the composition of the mother liquor reaches the quintuple point.
3. Take 100 lb. of melt of the composition CaO 30, Al_2O_3 20, and SiO_2 50% and cool until the mother liquor attains the composition CaO 25, Al_2O_3 15, and SiO_2 60%. Determine by molecular calculation and not by the levers what crystals have separated out and how much of each.

Shop technicians studying with Harry Thiemecke received an average grade of 88 in this examination; five received 100 and one received 34. This is an excellent showing in a very worth-while educational enterprise.

OHIO STATE UNIVERSITY

Ceramic Engineering Degrees, 1941

Professional Degree of Ceramic Engineer: LYMAN C. ATHY, (B.Met.E., 1923), Porcelain Enamel & Mfg. Co., Baltimore, Md.; ROBERT W. HOPKINS (B.Cer.E., 1931), 2444 Sanford Ave., Alton, Ill.; JOHN M. NEFF (B.Cer.E., 1928), 61 Jefferson Ave., Columbus, Ohio; WILLARD E. PALMER (B.Cer.E., 1929), Taylor, Smith, & Taylor Co., East Liverpool, Ohio; EDWARD C. SEABRIGHT (B.Cer.E., 1930), Electromaster, Inc., Detroit, Mich.; GEORGE H. SPENCER-STRONG (B.Cer.E., 1928; M.Sc., 1931), Porcelain Enamel & Mfg. Co., Baltimore, Md.; RAY T. WATKINS (B.Cer.E., 1918), U. S. Tariff Commission, Ceramic Div., Washington, D. C.

Doctor of Philosophy in Ceramic Engineering: WILLIAM C. BELL (B.S. in Cer.E., North Carolina State College of Agriculture and Engineering; M.Sc.), Greensboro, N. C.

*Master of Science in Ceramic Engineering:** HOWARD E. PETTY, Amherst, Ohio, Harbison-Walker Refractories Co., Pittsburgh, Pa., and HAL F. RANDOLPH, Anderson, Ind., 2nd Lt., 330th Infantry Corps, U. S. Army.

Bachelor of Science in Ceramic Engineering: WILLIAM G. COOPER, Columbus, Ohio (undecided); ARTHUR E. CURRIER, Columbus, Ohio, 2nd Lt., Corps of Engineers, U. S. Army; LAWRENCE D. HOWER, Osborn, Ohio, Carnegie-Illinois Steel Corp., South Works, Chicago, Ill.; ROBERT

* Probable positions of graduates are listed after their names.

S. HOWER, Osborn, Ohio, 2nd Lt., Corps of Engineers, U. S. Army; PHILIP P. IRWIN, Columbus, Ohio (undecided); JAMES H. JACOBI, Molino, Fla., 2nd Lt., Corps of Engineers, U. S. Army; WILLIAM H. LINKHORN, Columbus, Ohio, 2nd Lt., Corps of Engineers, U. S. Army; J. TED MCQUAIDE, Canton, Ohio, 2nd Lt., Corps of Engineers, U. S. Army; J. ALLEN PIERCE, Columbus, Ohio, Orton Fellowship, 1941–1942, Ohio State Univ.; DONALD E. POSTLEWAITE, Columbus, Ohio, Universal Sanitary Mfg. Co., Camden Division, Camden, N. J.; MALVERN M. REUTER, Columbus, Ohio, Assistant, Dept. of Ceramic Engineering, Ohio State Univ., 1941–1942; HOWARD F. RUSSELL, Columbus, Ohio, Nash-Kelvinator Corp., Grand Rapids, Mich.; WILLIAM J. SCHARFENAKER, Columbus, Ohio, Carnegie-Illinois Steel Corp., South Works, Chicago, Ill.; and A. WILLIAM WITZEMANN, Columbus, Ohio, Carnegie-Illinois Steel Corp., South Works, Chicago, Ill.

Ceramic Graduates in Defense Work

The Department received calls for fifty-five ceramic engineering graduates. The placement of graduates, however, was limited to defense and essential industries. Opportunities for undergraduates are abundant and all interested undergraduates will be placed in positions for the summer.

The Department is organizing for 1941–1942 to stress work in the branches of ceramics bearing on the essential defense industries.

Student Branch Meeting

H. M. Kraner of the Bethlehem Steel Corp., Bethlehem, Pa., spoke on "Use of Refractories in the Steel Industry" at a meeting of the Student Branch on May 14. Mr. Kraner, who has had extensive experience in spark-plug porcelains, mullite refractories, and refractories, included slides in his talk which showed the use and the results of using refractories in blast furnaces, Bessemer converters, and open-hearth furnaces.

UNIVERSITY OF ALABAMA

Student Branch Activities during 1940–1941

At a meeting of the Student Branch on October 24, Professor Le Clair, Head of the Department of Fine Arts, gave a talk on the design and making of pottery.

At the December meeting, Douglas McConnell of the McConnell Sales and Engineering Corporation addressed the Student Branch on "The Economics and Social Purpose in Industrial Organization." A lively discussion followed the talk.

At the meeting held in March, J. H. Varner, district manager of the Harbison-Walker Refractories Company, discussed the manufacture of silica and fire-clay refractories. This was a joint meeting with the Alchemists, and there was a large attendance.

At the last meeting in April, color films of the Carborundum Company showing thin sections of refractories with polarized light and reactions at high temperatures were presented. The meeting was concluded by a social gathering and refreshments were served.

The Student Branch cooperated completely in the Chemistry Day program held on April 18. Pottery was made by throwing and casting, sheet metal was enameled, and many other interesting displays were set up in the ceramic laboratories. The rapid quenching without cracking of the new Corning high-silica glass aroused much interest among the visitors.

Officers for 1941–1942

Officers of the Student Branch for 1941–1942 are as follows: *President*, Hershel Emison; *Vice-President*, Andrew Tencza; *Secretary*, Joseph Metz; and *Treasurer*, John W. Lewis.

—HOWARD P. CRAMMER, *Secretary*

REVIEW OF MINERAL INDUSTRIES EXTENSION WORK IN PENNSYLVANIA

Excerpts of article by H. B. Northrup from *Mineral Industries*, Pennsylvania State College, Vol. 10, No. 8, May, 1941.

History and Development of Extension Instruction

Mineral industries extension instruction was pioneered by The Pennsylvania State College. Mining extension was organized in 1893 and constituted what is believed to be the first vocational adult educational effort in that field in America. From 1894 to 1899, 27 extension bulletins were printed and distributed free for the benefit of classes in the coal-mining industry, and free lectures were delivered by a corps of teachers of the mining department of the College "to the mining employees at their customary place of assembly upon matters of interest to them in their occupation." In 1899, the State Legislature reduced the appropriation to the College and the extension pamphlets and lectures were discontinued.

From 1899 until 1919, several attempts were made to resume the extension services in mining through industrial grants for travel and publications and through voluntary contributions by members of the resident staff. The work consisted mainly of lectures and demonstrations and served the purpose of creating the desire for more training and additional information of a more formal character.

In 1928, the name of the School was changed, by trustee action, from School of Mines and Metallurgy to the School of Mineral Industries, and the working structure of the School was organized under the three functional, collaborating, interdependent divisions, viz., resident instruction, correspondence and extension instruction, and research. This functional organization is comparable with the organization of the College as a whole.

The federal Smith-Hughes law, passed in 1917, made federal and state funds available for vocational education. Mining extension was revived in 1919 and the College employed one full-time extension professor to reorganize the work and instruct the classes. In 1923, the State Department of Mines and the State Department of Public Instruction entered into a formal agreement with the School of Mining and Metallurgy to assist the College in its extension program. Classes were organized to study the State mining laws and State Department of Mines' previous examination questions and answers, in preparation for coming State examinations for certification of competency as underground officials. Mimeographed lesson material was used at first, and in 1927 and 1929 mining instruction and mining teacher-training lessons were printed in pamphlet form.

In 1931, the extension activities of the School were placed on an organized basis compatible with the newly reorganized School of Mineral Industries and a director was appointed to take full charge of the work. During that year, at a conference in Harrisburg, an agreement was consummated between the State Departments of Public Instruction, Mines, Labor and Industry, and the College, whereby extension classes in the field of the mineral industries could be organized by the College throughout the State under "public supervision and control" in close cooperation with the State Department of Public Instruction, the other State departments collaborating.

Teachers Chosen from Industry

Extension class teachers are (1) selected from local industries by the extension supervisors, (2) recommended by them to the local school districts for election to teach specific subject matter, (3) elected by the school boards of the districts as regular members of the teaching force, and (4) equipped by the State Department of Public Instruction with a Vocational Extension Certificate, good for one year and renewable if their services have been satisfactory. Because they are employed locally, they are appreciative of the educational needs of the groups they serve as well as the local social and economic conditions which have a direct bearing on all local educational programs. Each

teacher must have an educational background that meets the requirements of the College and he must also have had at least six years of industrial experience (or its equivalent) in the industry from which his vocational pupils come.

A class may be started anywhere in the State on petition by a sufficient number of men, all of whom shall be residents of the local school district. The instruction is given on a three-year basis, and the College prefers that no program be started in any center with an enrollment of fewer than 25 men. These men shall be over 18 years of age and employed in the industry for which the training curriculum was prepared. Natural mortality accounts for a registration of about 15 of these same men for the third year of the work. Each student pays a $5.00 registration fee; of this amount, $2.50 to $3.50 purchases his textbook and the remainder is refunded if he attends 75% of his scheduled class hours. This constitutes his total expenditure for a minimum of 144 hours of class instruction.

The scope of the work of the extension classes of the division in Pennsylvania for 1940–1941 is summarized in Table I.

TABLE I

Curriculum	Centers	Classes	Counties	Teachers	Enrollment
Ceramics	7	8	7	8	152
Metallurgy	18	50	14	50	1173
Coal Mining	60	77	16	61	1788
Mine Mechanization	4	9	3	9	500
Petroleum and Natural Gas	8	31	8	31	721
Total	106	188	49	166	4334

The supervisory force of the division is limited by State appropriation and the present staff can handle adequately an enrollment of approximately that given in the table. Many requests are received annually for new classes in all of the extension curricula, some of which have to be deferred because of inability to organize and supervise them according to present standards.

NOTES FOR CERAMISTS

W. W. COFFEEN P.E.I. RESEARCH ASSOCIATE

G. H. McIntyre, research director of the Ferro Enamel Corporation and chairman of the Research Associate Committee of the Porcelain Enamel Institute, has announced the appointment of William W. Coffeen as research associate for the Porcelain Enamel Institute at the National Bureau of Standards, Washington, D. C. The work of the research associate, which has been ably carried on by Paul L. Smith for the past three years, is supervised by the Research Associate Committee.

Mr. Coffeen has been instructor in ceramic engineering at the Georgia School of Technology, Atlanta, Ga.

REPORT ON GEOLOGY OF NEW JERSEY

The Division of Geology and Topography of the New Jersey Department of Conservation and Development has issued a revision of Bulletin No. 50, "The Geology of New Jersey" by J. V. Lewis and H. B. Kummel. The report, which was originally published in 1914, has been revised and rewritten by H. B. Kummel, former state geologist of New Jersey, who summarizes all the knowledge that has been gained so far of the complex geology of New Jersey. The bulletin contains fifteen illustrations and 203 pages of text and may be purchased for 35 cents from the Department of Conservation and Development, State House Annex, Trenton, N. J.

PACIFIC NORTHWEST CLAYWORKERS' ASSOCIATION

The Pacific Northwest Clayworkers' Association will hold its summer meeting on July 18, 1941, at Spokane, Washington. The following program has been arranged.

9:30 A.M.: Visit Gladding, McBean & Co. plant at Mica and nearby clay pits.

12:15 P.M.: Lunch at Davenport Hotel, Spokane (75 cents).

1:30 P.M.: Visit Washington Brick & Lime Co. plant at Dishman.

6:30 P.M.: Dinner at Davenport Hotel ($1.25). Eric Johnston, vice-president of the U. S. Chamber of Commerce, will speak on "Behind the Scenes at Washington."

—CARL H. ZWERMANN, *Secretary*

ELECTROCHEMICAL SOCIETY AUTUMN MEETING

The Electrochemical Society will hold its autumn meeting in Chicago, Ill., October 1–4, 1941, at the Hotel Knickerbocker. Three of the five technical sessions will be devoted to discussions of electrodeposition and electroorganic and miscellaneous topics.

E. M. HOMMEL HEADS O. HOMMEL COMPANY

Ernest M. Hommel has been elected president of the O. Hommel Company to succeed his father, Oscar Hommel, who died in April, 1941. Mr. Hommel has been actively associated with the Company for the last eight years as a sales representative, and he has been vice-president since 1929.

Ernest M. Hommel

Dead Line!

is September 21—for advertising copy to be used in the October 1941 Membership Roster of The American Ceramic Society.

The Membership Roster is an up-to-date list of all the paid members of The Society. It will be referred to constantly and therefore is an effective sales message opportunity.

Number of Insertions

	1 month	*3 months*	*6 months*	*12 months*
Full page	$66.00	$60.00	$52.00	$44.00
Half page	36.00	33.00	30.00	26.00
Quarter page	20.00	18.00	16.50	15.00
Eighth page	10.75	9.90	9.00	8.25

Classified advertisements: 35 words for $1.10 per insertion

Cover positions: list plus 25%

First page preceding or following reading matter: list plus 20%

Color rates: on application

Reading notices not accepted

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2525 N. HIGH ST. COLUMBUS, OHIO

THE OFFICIAL SOCIETY KEY

The Society Key is an attractive piece of jewelry in yellow gold with blue enamel. The size of the key is about 1¼ inches by ¾ of an inch.

The key is available with the inscriptions of "Member," "Fellow," or "Student."

The price of the gold-filled key is $3.25 and the solid gold key may be purchased for $6.50.

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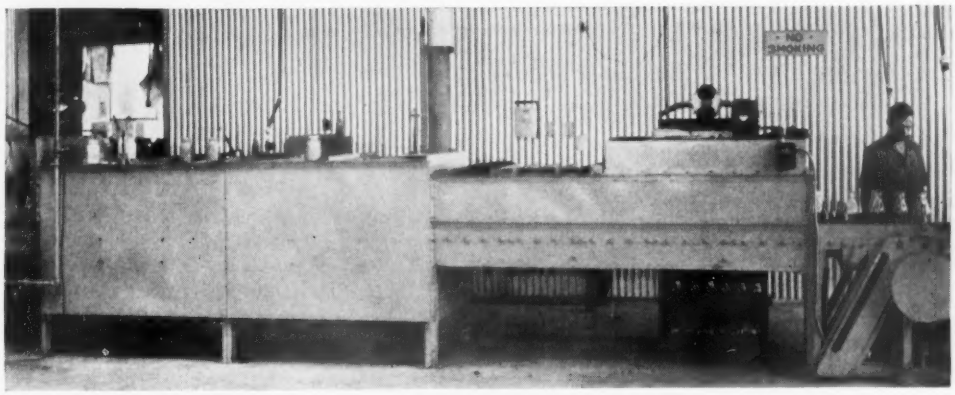

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The Hommel, O., Co., Inc.
Norton Co. (*Alundum-Crystolon*)

Air Conditioning Systems
Frazier-Simplex, Inc.

Aloxite (Refractory Products)
Carborundum Co.

Alumina (Hydrate and Calcined)
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.
The Vitro Mfg. Co.

Alumina (Fused) Brick and Tile
Electro Refractories & Alloys Corp.
The Vitro Mfg. Co.

Aluminum Oxide (Calcine)
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Aluminum Oxide (Fused)
Carborundum Co.
Electro Refractories & Alloys Corp.
Harshaw Chemical Co.
Norton Co.
The Vitro Mfg. Co.

Alundum (Refractory Products)
Norton Co.

Ammonium Bicarbonate
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Solvay Sales Corp.

Ammonium Bifluoride
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Ammonium Carbonate
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Antimony Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Antimony Sulphide
Foote Mineral Co.
The Hommel, O., Co., Inc.

Arches (Interlocking, Suspending, and Circular)
Frazier-Simplex, Inc.

Arsenic
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.

Automatic Brick Car Loaders
Lancaster Iron Works, Inc.

Ball Mills
Ceramic Color & Chemical Mfg. Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
McDanel Refractory Porcelain Co.
The Vitro Mfg. Co.

Ball Mills (Laboratory Type)
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
The Vitro Mfg. Co.

Barium Carbonate
Ceramic Color & Chemical Mfg. Co.
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Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Porcelain Enamel and Mfg. Co.

Magnesite
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Magnesite Calcined
Foote Mineral Co.
The Hommel, O., Co., Inc.

Magnesium Carbonate
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Manganese
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Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Manganese Dioxide
Drakenfeld, B. F., & Co.
Foote Mineral Co.

Manganese (Oxide)
Ceramic Color & Chemical Mfg. Co.
Corhart Refractories Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Masks (Breathing)
Drakenfeld, B. F., & Co.

Metals (Porcelain Enameling)
American Rolling Mill Co.

Micronized Products
Porcelain Enamel and Mfg. Co.

Microscopes (Polarizing)
Bausch & Lomb Optical Co.

Minerals
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Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Mixers
National Engineering Co.

Mixers (Batch)
Lancaster Iron Works, Inc.
National Engineering Co.

Mixers (Concrete, Paving, Road Paving, Plaster, Asphalt, Truck, Mortar, Bituminous)
Lancaster Iron Works, Inc.

Mixers (Laboratory)
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National Engineering Co.

Mold Sanders
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Muffles (Furnace) (Laboratory)
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Electro Refractories & Alloys Corp.
Frazier-Simplex, Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Norton Co.

Mullers (Batch)
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National Engineering Co.

Muriatic Acid
Denver Fire Clay Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Pennsylvania Salt Mfg. Co.

Needle Antimony
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Nepheline Syenite
Great Lakes Foundry Sand Co.

Nickel Salts
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Nitrates (Cobalt, Sodium)
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
The Vitro Mfg. Co.

Nitre
Harshaw Chemical Co.
The Hommel, O., Co., Inc.

Norbide (Norton Boron Carbide)
Norton Co.

Olivine
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Opacifiers
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Metal & Thermit Corp.
Pennsylvania Salt Mfg. Co.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Overglaze Colors
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Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.

Oxides
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel, O., Co., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Metal & Thermit Corp.
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The Hommel, O., Co., Inc.

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Industrial Ceramic Products, Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Louthan Mfg. Co.
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	Aluminum oxide (Al_2O_3)	39.47
	Titanium oxide (TiO_2)	1.29
	Ferric oxide (Fe_2O_3)	0.55
	Lime (CaO)	0.00
	Magnesia (MgO)	0.00
	Alkalis (Na_2O,K_2O)	0.00
Mechanical Composition	—20 microns	98.00%
	—10 "	80.98
	— 6 "	70.94
	— 3 "	54.70
	— 1 "	37.74
	— 0.5 "	21.75

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